Seminar „ Aktuelle Themen der Strassenplanung”

„Vereinigung der Strassenbau- und Verkehrsingenieure in Nordrein-Westfalen „ (VSVI-NRW)

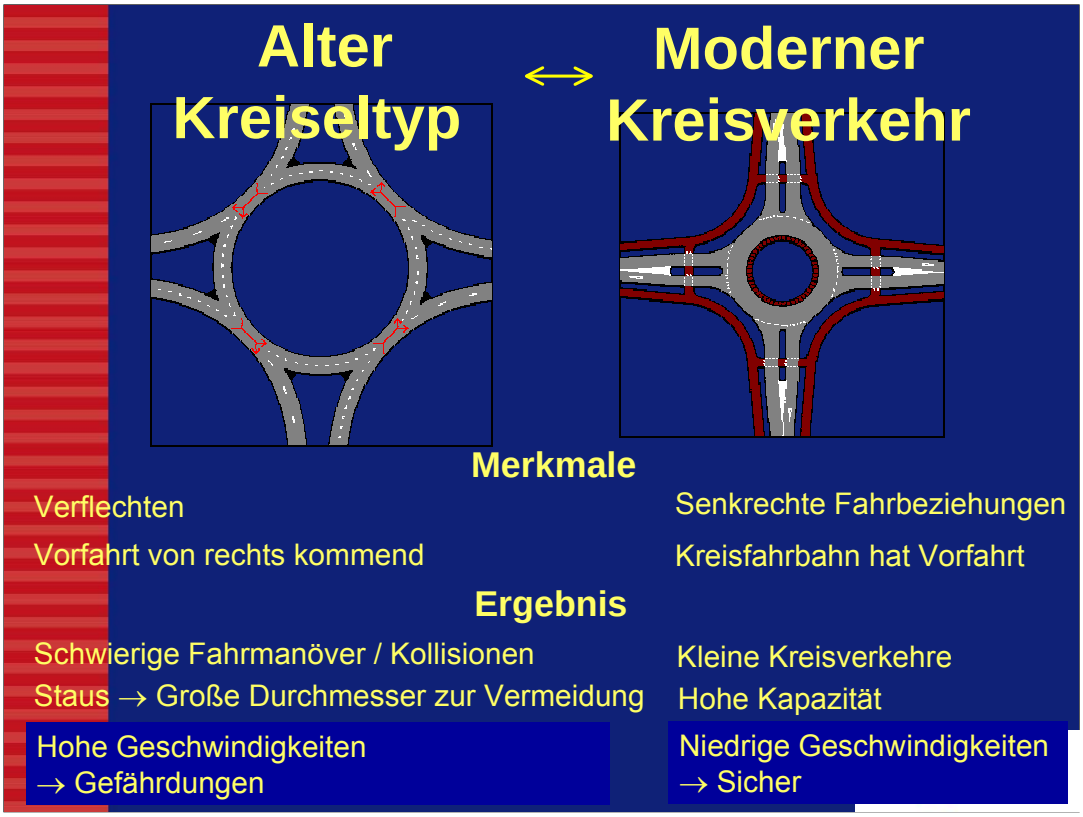
Donnerstag, den 25. Januar 2007 in der

Bundesanstalt für Strassenwesen (BASt) in Bergisch Gladbach (20 km Östlich von Köln)

Ladies and gentlemen,

To start with, I would like to apologise for my bad English and my worse German.

I cannot really cope very well with other languages than my native language. As my English is better then my German, I will give this presentation in English



First of all, it is important to realise the differenc between the OLD ROTARY and the MODERN ROUNDABOUT. What were the features of the old rotary?

- Weaving movements on the circulatory roadway
- Traffic coming from the right (traffic on the approaching roadways) had the right-of-way.

But what was the result?

- Weaving over a small distance leads to many collisions
- The rotary became quickly congested. When this problem was countered by building rotaries with larger inscribed circle diameters motorists merely increased their speeds, and
- More serious accidents occurred. Especially accidents involving pedestrians and cyclists were particularly bad.

Features of modern roundabout

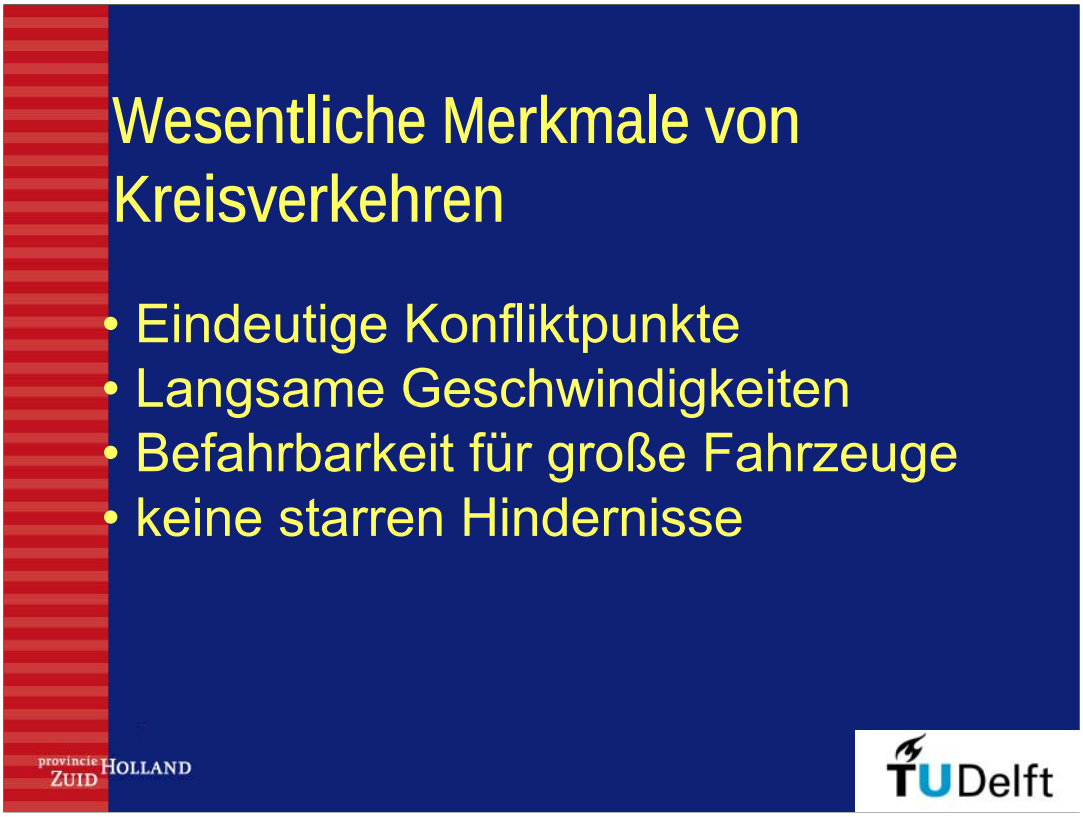
- Conflict points are obvious by the connecting roadways intersecting the roundabout at a 90 degree angle.
- Right- of-way on the roundabout

Result:

- small roundabout with a large capacity
- low speed and a few injury accidents.

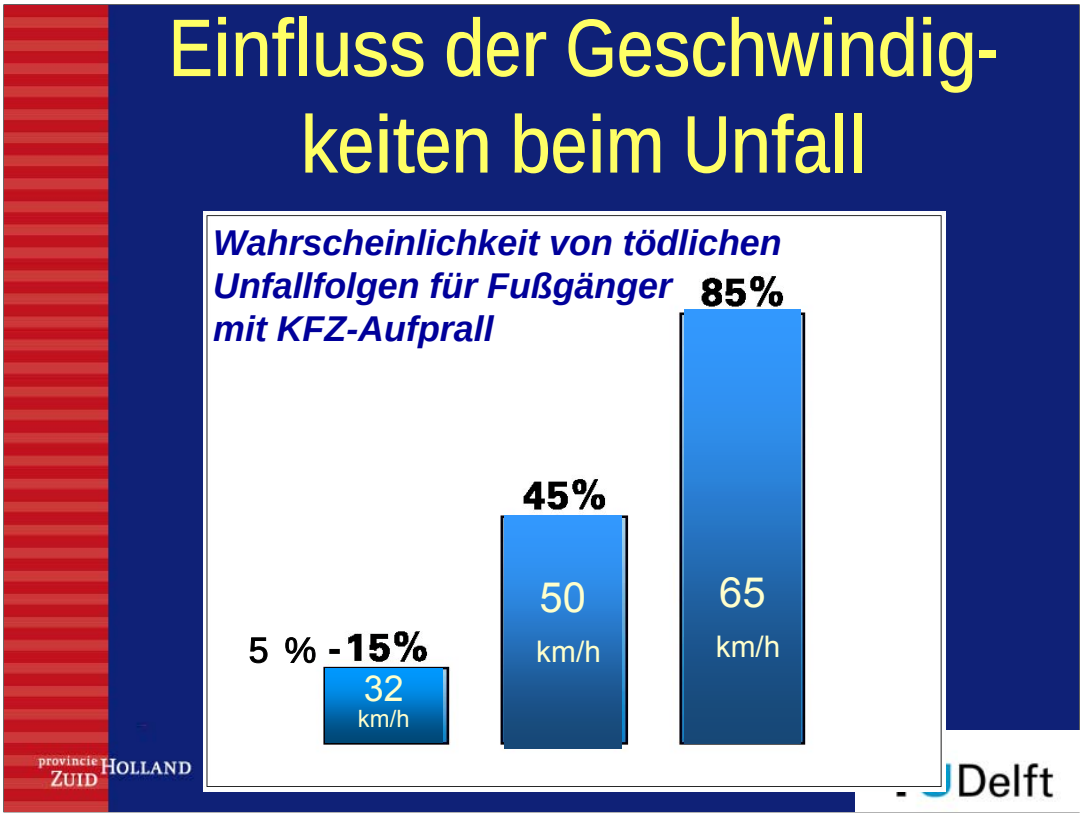
The speed reduction of all traffic is important for all roundabouts in the Netherlands.

This is a roundabout outside built-up areas. Give your attention on the design of the tracks for mopeds and bicycles. This design reduces also the speed of mopeds and cyclists.



The key characteristics of a modern roundabout are:

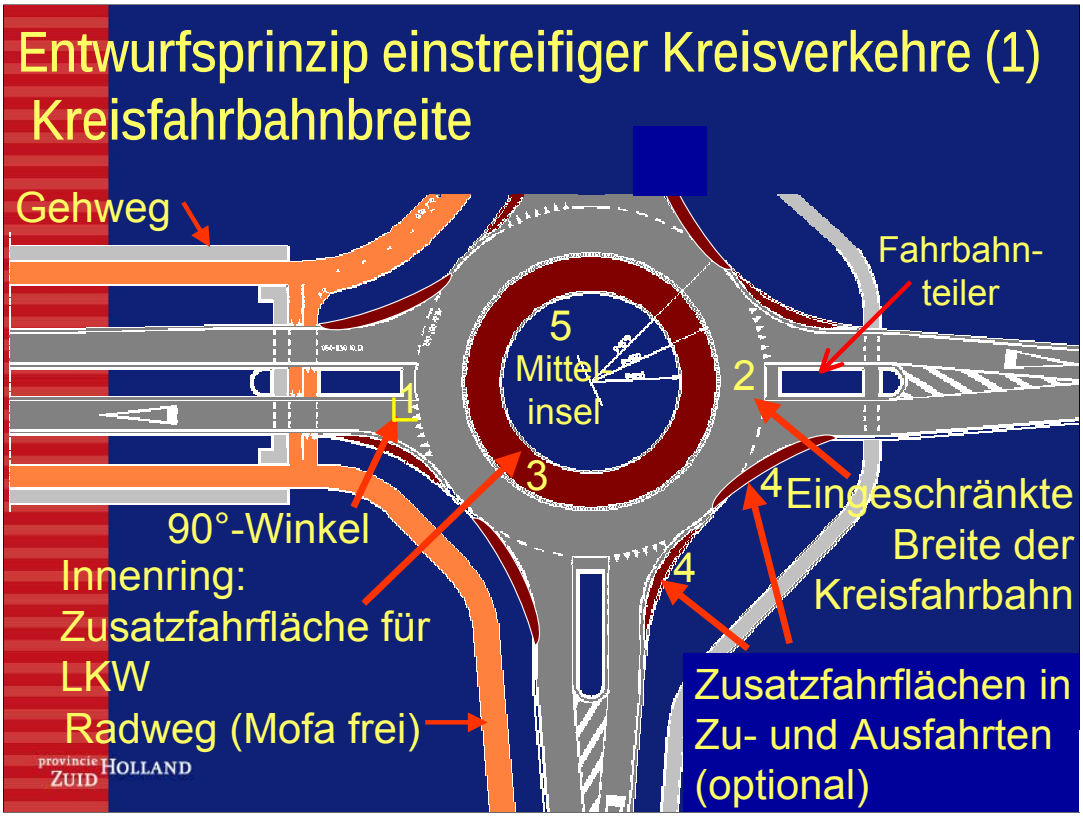
- Unique conflict points
- Low speeds
- Suitable for large vehicles
- Only forgivable obstacles for entering vehicles



Impact of Colission-speed

Research has shown that there is a high correlation between collision-speed and the risk of fatal injury.

This exhibit shows that a reduction of speed from 50 kilometres an hour to 32 km/h, decreases the pedestrian's chances of death by a factor of about 5.



Design requirements for Single-Lane Roundbouts

The design of single-lane roundabouts has to do with the solving of dilemmas.

The first dilemma concerns the width of the Roundabout-Lane.
Safety requirements leads to a rather narrow lane,
whereas suitability for trucks leads to ample space.

So, the question is: how to realize speed reduction and keep roundabouts accessible for heavy traffic?
Here you see a solution for the combination of the requirements for safety and accessibility

(1) A 90-degree angle between approach and circulatory roadway
(2) Limited width of circulatory roadway.
(3) Central apron offers an additional roadway width for trucks.
(4) Aprons in the axils (armpits) between entrance and roundabout and exit and RA which also offers an additional roadway for trucks.

("Roundabouts, An informational Guide", exhibition 6-5 in the section entitled "Design Speeds, subsection 6.2.1.2, Federal Highway Administration)

The second dilemma is about the radius itself.

This dilemma consists of two parts

First the dilemma regarding *only safety (2a)*
- Low speeds at the RA require a small radius
- Low speeds for straight on going vehicles require a large radius.

The second dilemma is *between safety and capacity* (2b)
- The Capacity requirement is: splitter islands of branches not too small;
- The Safety requirement is: splitter island not too large, because then vehicle tracks become too smooth.

Wider central islands require a larger RA radius to obtain an optimal speed reduction

Increasing vehicle path curvature – that means decreasing the radius of the vehicle path curve – can be reached by increasing the roundabout radius up to an optimum, which depends on:
- the angle between the connecting legs;
- the width of the circulatory roadway;
- the width of the splitter islands in the connecting legs.

Figure 4 in CROW-publicatie 24

When the angle between the legs is between 90 and 180 degrees, then the pass-through speed will increase substantially. To reduce the speed, you have to increase the roundabout radius.

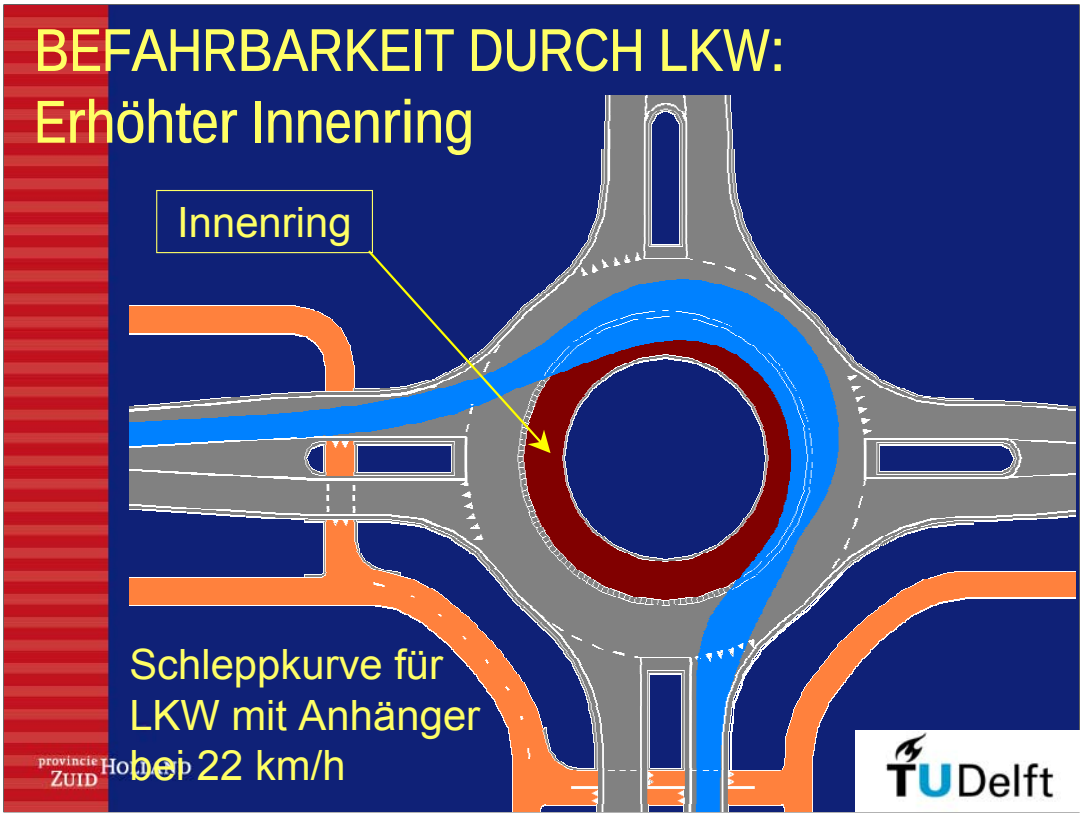
Summarizing:
The requirements of safety are:
- Low roundabout's traffic speed: roundabout radius should not to be too large.
- Low pass through speed: roundabout radius not too small.

versus

The requirements of capacity:
- Is there enough time for detecting cars leaving the roundabout at the same leg as you are entering? That means that the splitter island width has not to be too small.

It is a challenge to find the optimum measure of all the basic elements of the roundabout:
-The angle between the connecting legs.
-The roundabout radius.
-The width of the circulatory roadway.
-The width of the splitter islands in the connecting legs.

.



Drawing made with program CURSIM.

SUITABILITY/ (RIDIBILITY) OF ROUNDABOUTS FOR TRUCKS

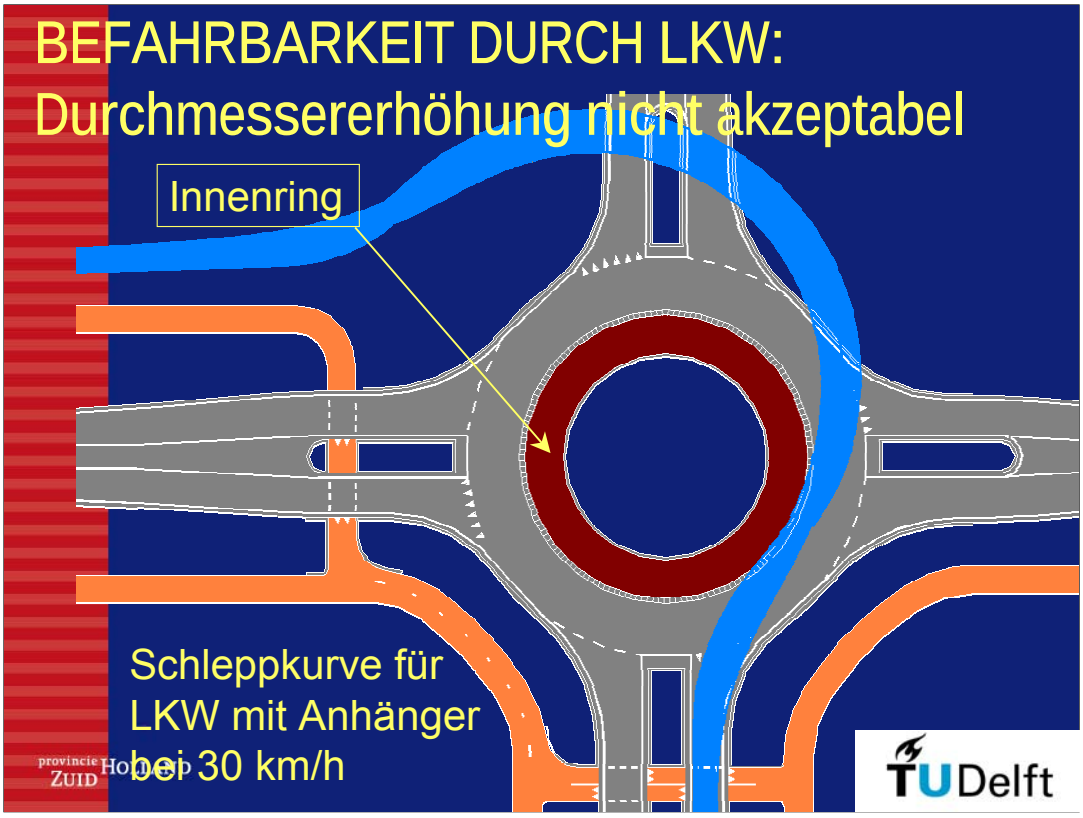
We show here the vehicle path of an articulated truck at a single lane Roundabout. It uses the central apron to a large extent, whereas its speed is only 22 km/h.

The aprons should not be too steep. We prefer that an apron around the central island of the roundabout should:

- Be separated from the carriageway by a rumble strip rising 7 cm over 10 cm;
- Has the same super elevation as the carriageway

This will prevent cars using it and will not give unnecessary discomfort for trucks

Mountable rumble lanes in the axils of the connecting branches will improve the rid ability for trucks without inviting cars to choose a speed too high.



Drawing made with program CURSIM.

Continuation

RIDABILITY OF ROUNDBOUTS FOR TRUCKS

There is no fear that trucks will use RA's with a too high speed.

This picture shows a vehicle path, of the same truck as before, when its speed is 30 km/h. Making this possible would lead to far too large RA's.

However, it is wise to choose the dimensions of aprons in such a way that at speeds higher than 25 km/h the discomfort is such, that vans will not use them.

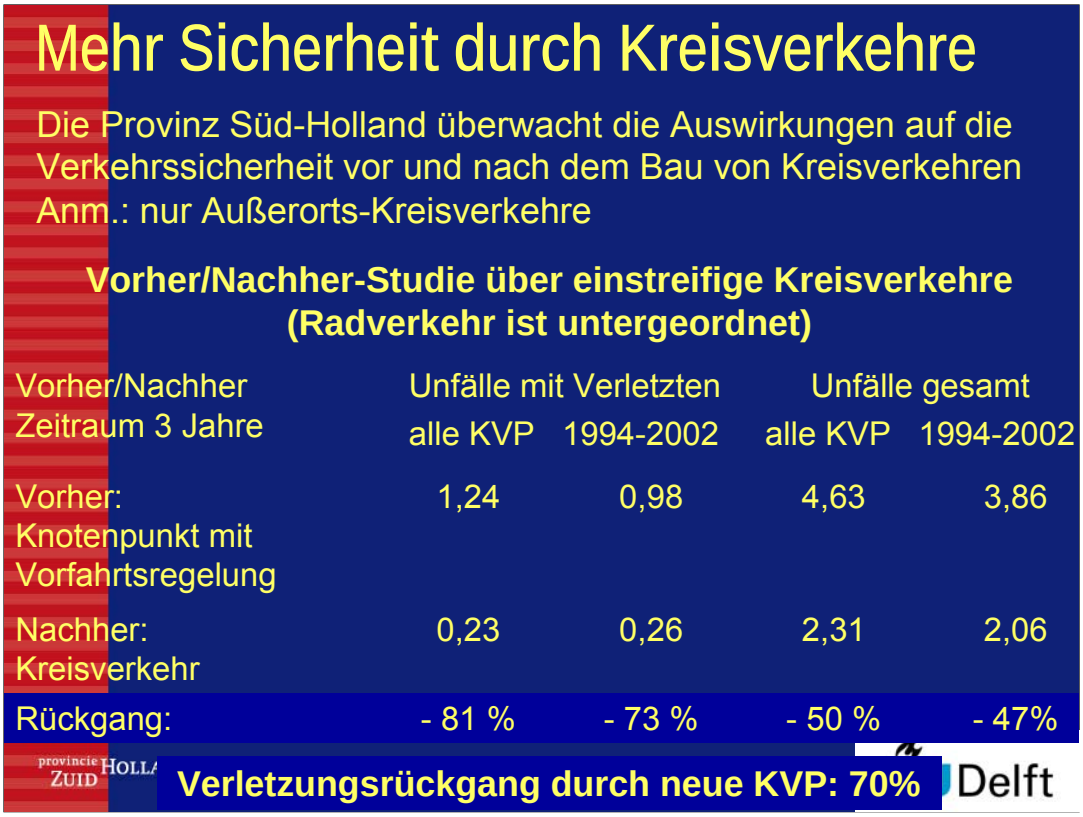
Boven:*rotondeschild, licht van gewicht en zo geconstrueerd (bevestigd aan twee gegalvaniseerde ijzeren paaltjes die er achter staan), dat de verbinding bij aanrijding zo lang mogelijk intact blijft en in zijn geheel naar achteren klapt.*
Onder: *rotondeschild in een aluminium portaalconstructie die bij aanrijding bij de grond kan afbreken en in stukken vliegt.*

Finally the effect of obstacles on the RA island
The requirement of Stainable Safety means that the roundabout-shield in case of a collision should bent down totally *(Above)* and not break into pieces *(Below),* that could break the windshield of a car and cause injuries for the car occupants.

This requirement of safe post crash behavior holds for all objects in the central island.

With all these requirements, the modern single lane roundabout is a safe solution for intersections.

At spots where the province Zuid/Holland intersections replaced by single-lane roundabouts, we found a reduction of casualties of 70 till 80 percent.



Effect on safety of the building of RA at priority intersections

The table shows the results of the monitoring of the safety effects of the building of RA's at the road network of the province of Zuid-Holland until 2003.

It should be remarked that the safety effect will gradually become less because the more dangerous intersections were rebuilt first.

This is illustrated by the reduction percentage of RA's built after 1994, having a reduction of only 73 % (in stead of 81%).

We therefore recommend to use a percentage of 70 as a general applicable number.

Effect of Roundabouts on Safety of Vulnerable Road Users

Owen Arndt and Rod Troutbeck at International Symposium on Highway Geometric Design Practices in 1995 stated:

“Numerous studies show: “Roundabouts are a safer intersection type for vehicle occupants and pedestrians, but may be more dangerous for cyclists.”

Nevertheless by comparing 27 intersections before and after the building of roundabouts by province South-Holland we found the reduction of casualties among cyclists and moped riders to be in the same range as the reduction of casualties among motorist, (both reduced by about eighty percent).

Cyclists' Safety related to the Right-Of-Way

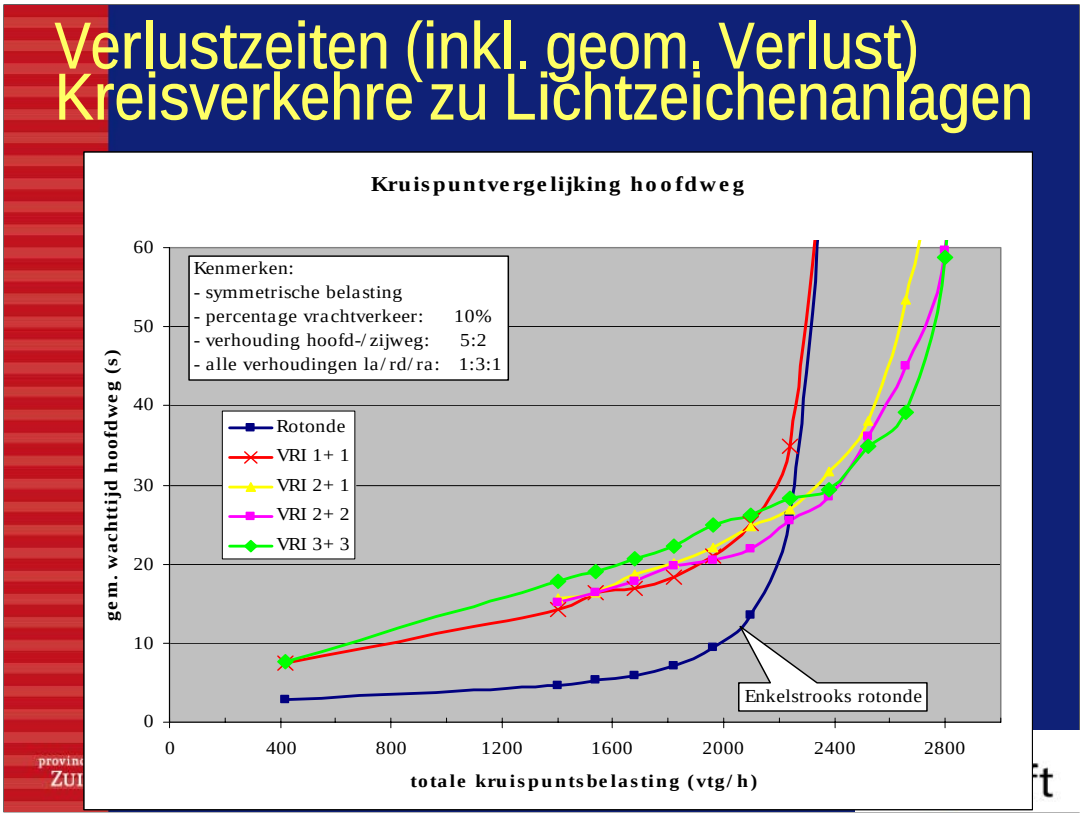
The SWOV Institute for Road Safety Research in the Netherlands did some research after the safety of different kinds of priority for cyclists at roundabouts.

Summarizing

It is possible to state, that on Roundabouts where cyclists have right of way compared to roundabouts where slow traffic has to yield right-of-way, the differences are:

- Two times as many injury accidents;
- Four times as many injury accidents with cyclists.
- Seven times as many hospitably accidents.

The conclusion may be: single-lane roundabouts are the safest type of intersections.



Delay related to traffic volume

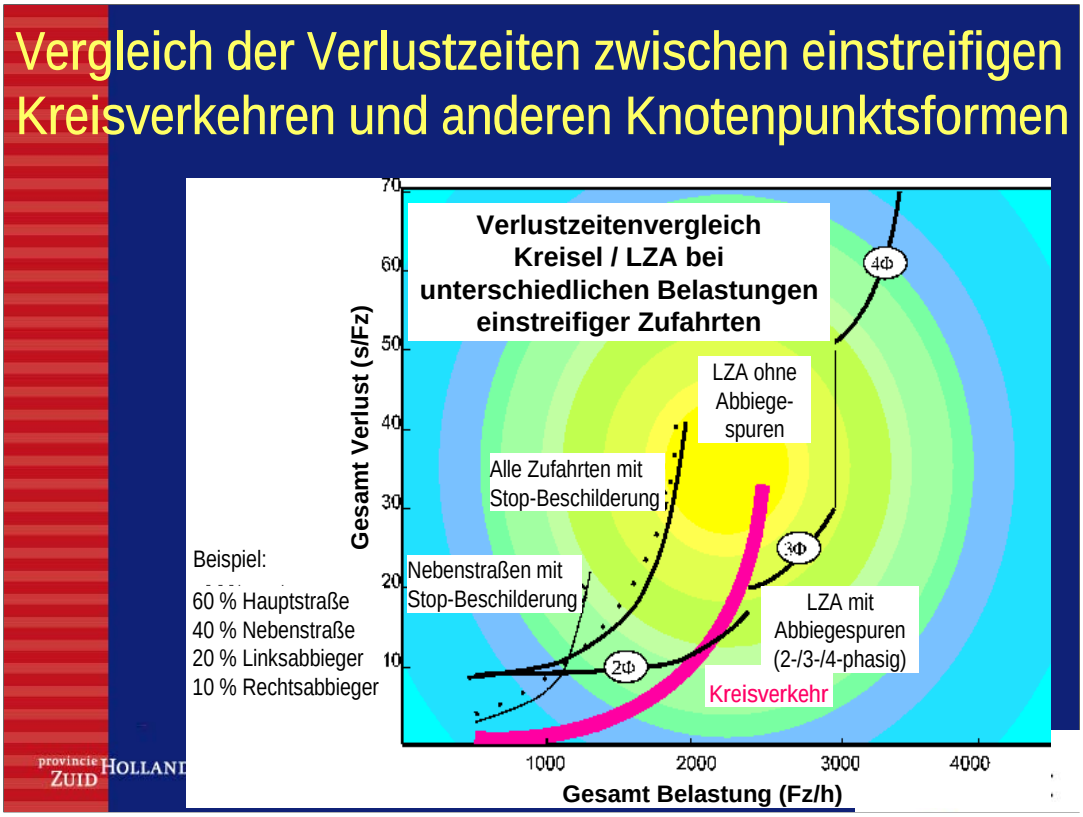
Perhaps, you will question the quality of traffic flow at this type of roundabouts.

Here you see a comparison of roundabouts and traffic lights, which Martijn de Leeuw has calculated by a simulation model HUTSIM at Delft University of Technology.

Horizontally you see the total traffic volume, that enters the roundabout.

Vertically the average delay at the main road, inclusive geometric delay (because of speed reduction or a larger route).

As the volume does not reach the capacity limit, the delay at a roundabout is obviously less than at a signalized intersection (as you can see at the graph).



Here you see a calculation of the Florida University of the delay and the traffic volume

Horizontally you see the total traffic volume, that enters the roundabout, measured in vehicles per hour.

Vertically the average total delay

Four types of intersections are compared:

- **Two-way stop-control**
- **Four-way stop-crossing** (All-Way Stop-Control, presented by a dotted line)
- **Crossings controlled by traffic lights** in four variants:
  - Without turning bays (the delay is high and the capacity is small)
  - Two phase controller (with turn bays). /feiz/
  - Three phase controller (,,).
  - Four phase-controller (,,).
- **Single-lane roundabout**

Essentially you see the same result. It is obvious that below a certain traffic volume the delay on a single-lane roundabout is lower than on all other types of intersections. In the case of the distribution of traffic flows over the directions, used in this study by the University of Florida, the limit of the volume entering is 2.500 vehicles per hour. Above that volume, signalised intersections cause less delay than the single-lane roundabout, if there are enough turning bays.

Problem Definition Development New Types of Roundabouts

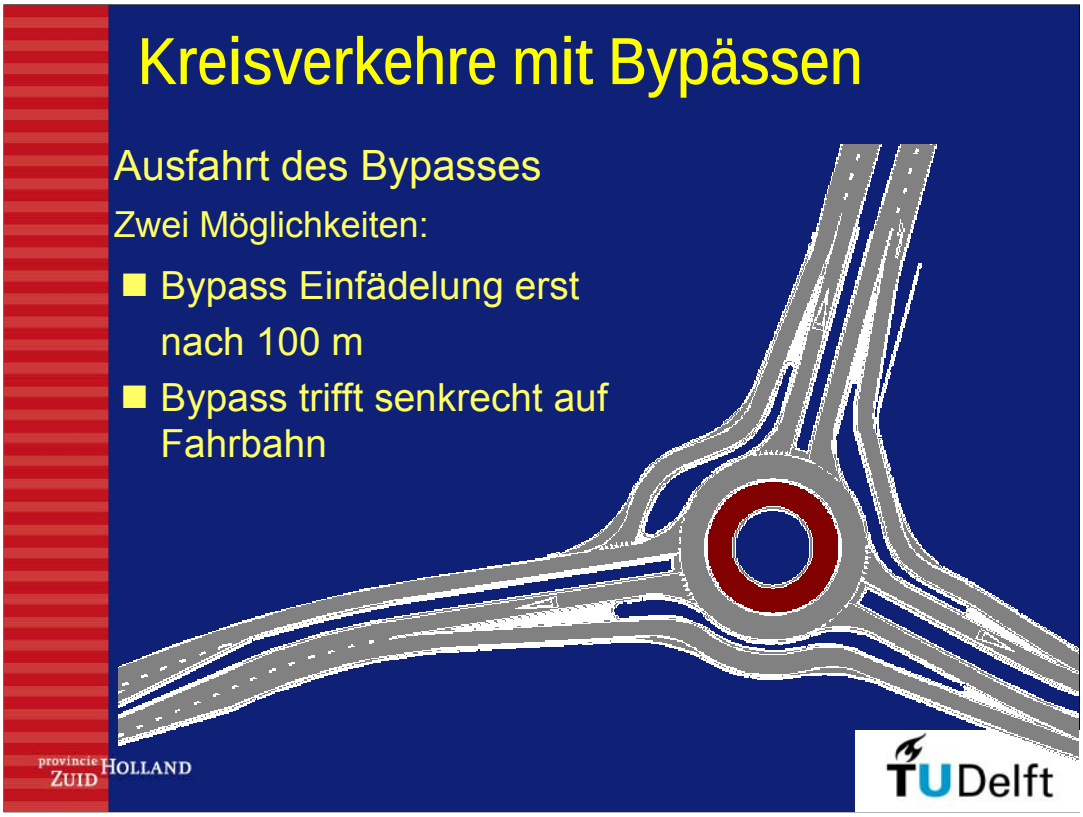
In 1997 the province ZH had built 85 single-lane RA's. But at many spots that required a roundabout we found that capacity of a single lane type would not be sufficient.

The following dilemma presented itself.

A double-lane RA causes a lot of side swipe collisions. In the past for that reason we replaced old rotaries by a signalized intersection. But afterwards we saw again an increase of injury accidents, especially with vulnerable road users, it.est (i.e.) pedestrians, bicyclists and mopeds.

How to solve this problem?

Anyhow it has lead to a lot of new ideas and creativity.



Passing-Lane Roundabout

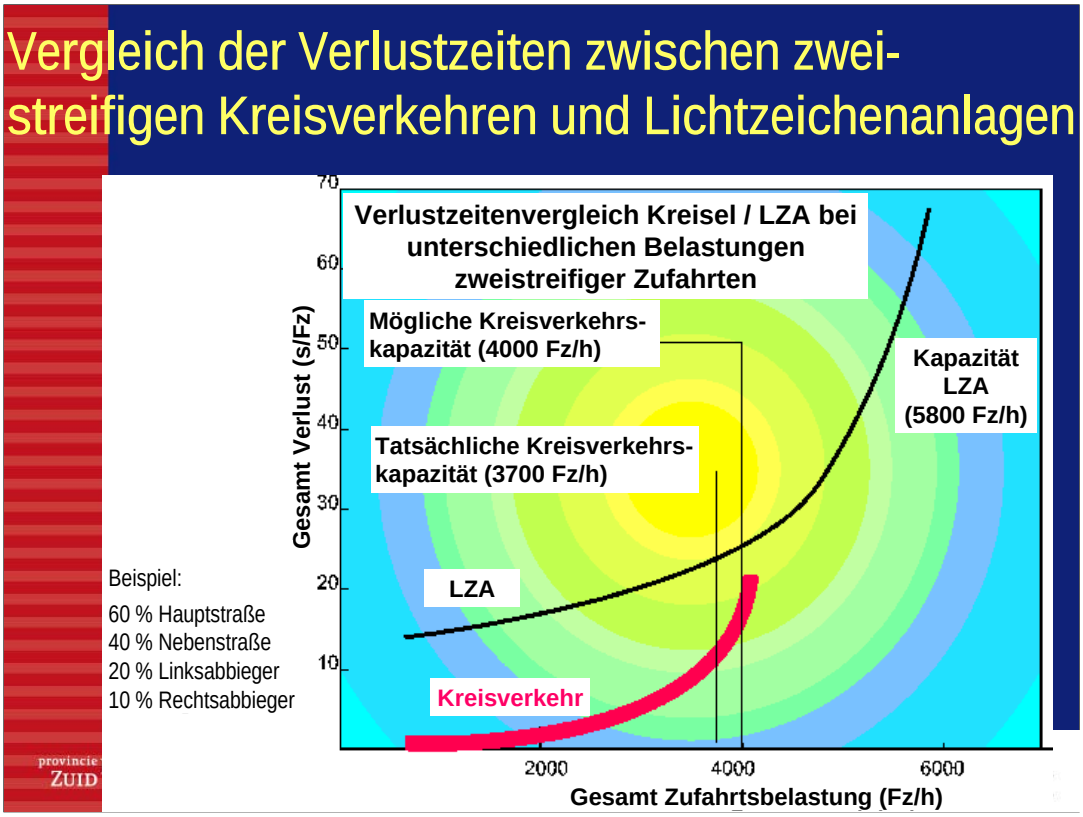
A passing lane RA is essentially an ordinary single lane RA with extra carriage ways added, that pass by the circular part of the RA

A critical point forms the end of the by-pass.

There are 2 solutions

- A parallel lane of a length of a 100 m
- A perpendicular connection to the exit lane (not skew as in CROW Guide Lines; that results into a bad view angle)

Problem
Heavy through going volumes can not be handled satisfactory at such a RA with 4 legs.
Then we need double-lane roundabouts.

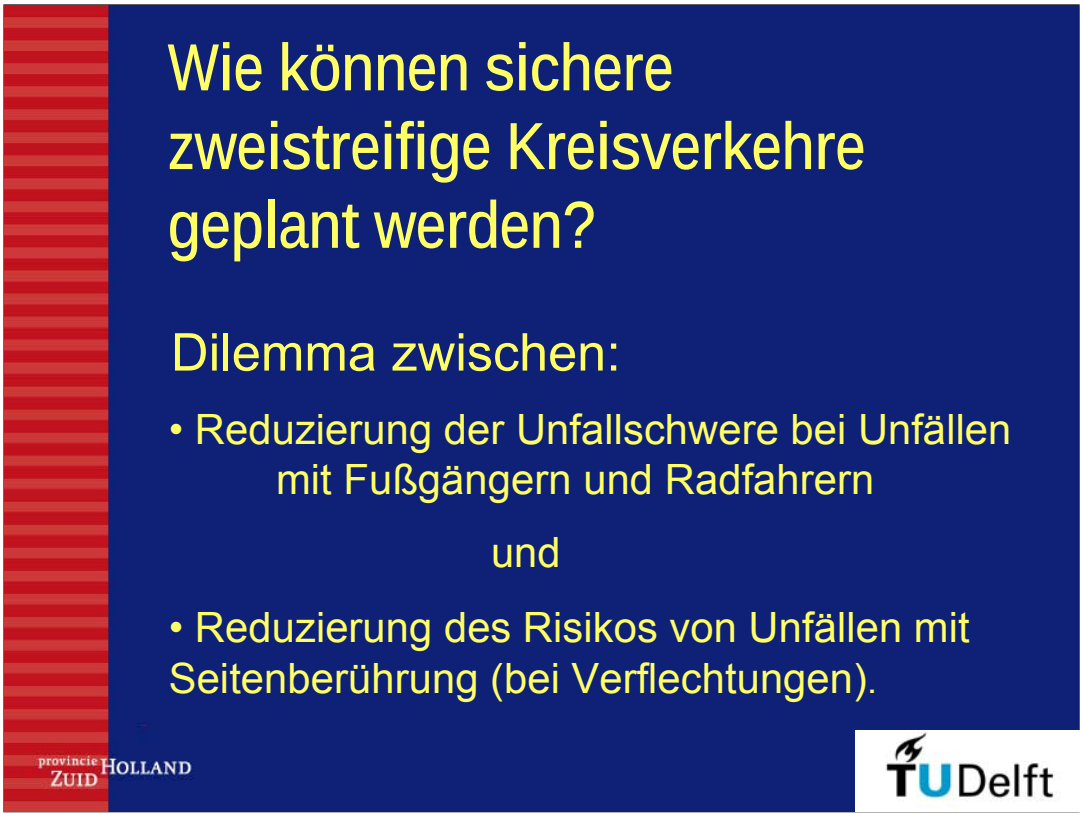


Comparison Delays Double-Lane Roundabouts and Traffic Lights related to Traffic Volumes

Here a double-lane roundabout is compared with a signalized intersection.

This picture shows that there is a domain of traffic volumes where double-lane roundabouts have preference above traffic lights.

So, in the Netherlands with a lot of bicycles and mopeds, it is very important to have concepts to design two-lane roundabouts which are also safe for the more vulnerable road users.



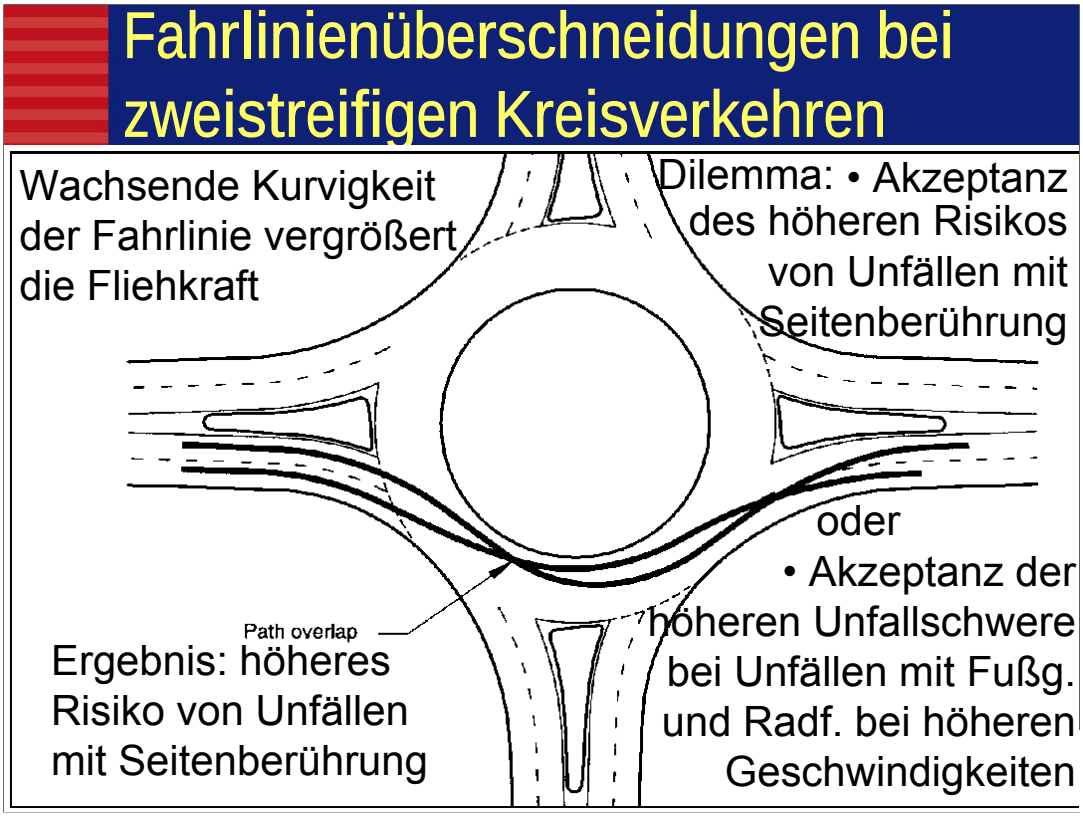
Safety Dilemma of Double-Lane Roundabouts

- But the problem is: How does one design safe double-lane roundabouts?

(2) Then we meet with the dilemma between:

- - Reducing the severity of collisions especially with vulnerable road-users and

(4) - Reducing the risk of sideswipe collisions (or in British English: sideways collisions).



Path Overlap at a Double-Lane Roundabout

(1) I will illustrate that dilemma with this picture.

At multi-lane roundabouts increasing vehicle path curvature creates greater side friction between adjacent traffic streams,

(2) which can result in more vehicles cutting across lanes, increasing risk of sideways collisions.

(3) So, as I have said, we need to deal with a dilemma between:

(4) Accepting higher risk of sideswipe collisions

or

(5) Accepting higher severity of collisions with vulnerable road users by higher speed of fast traffic.

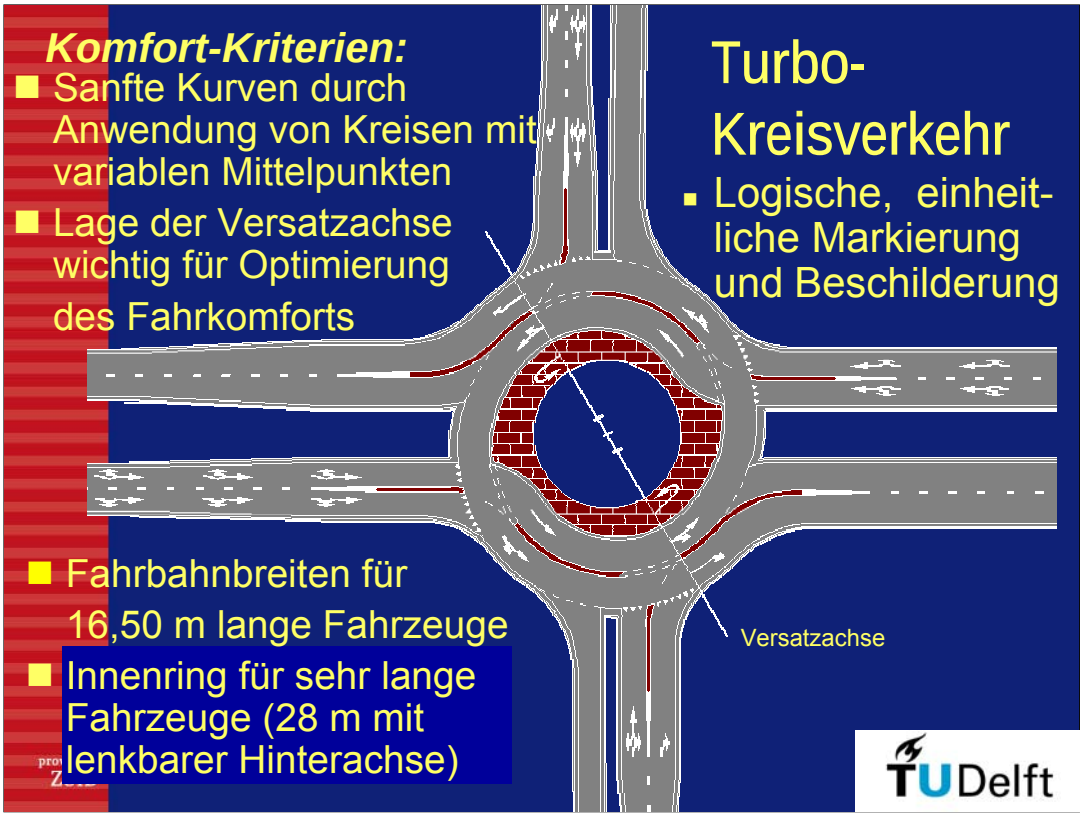
This is one of the problems of the conventional concentric two-lane roundabout

The Challenge was to develop a roundabout
- with a higher capacity than a single-lane roundabout and a roundabout with passing-by facilities
- but with the same safety characteristics.

The preconditions for that solution are:

- no weaving at the roundabout;
- yield to no more than two lanes;
- low speeds.

The result is called Turbo-Roundabout.



How can we fulfill the requirements in the design?

Characteristics relating to **comfort** for the users

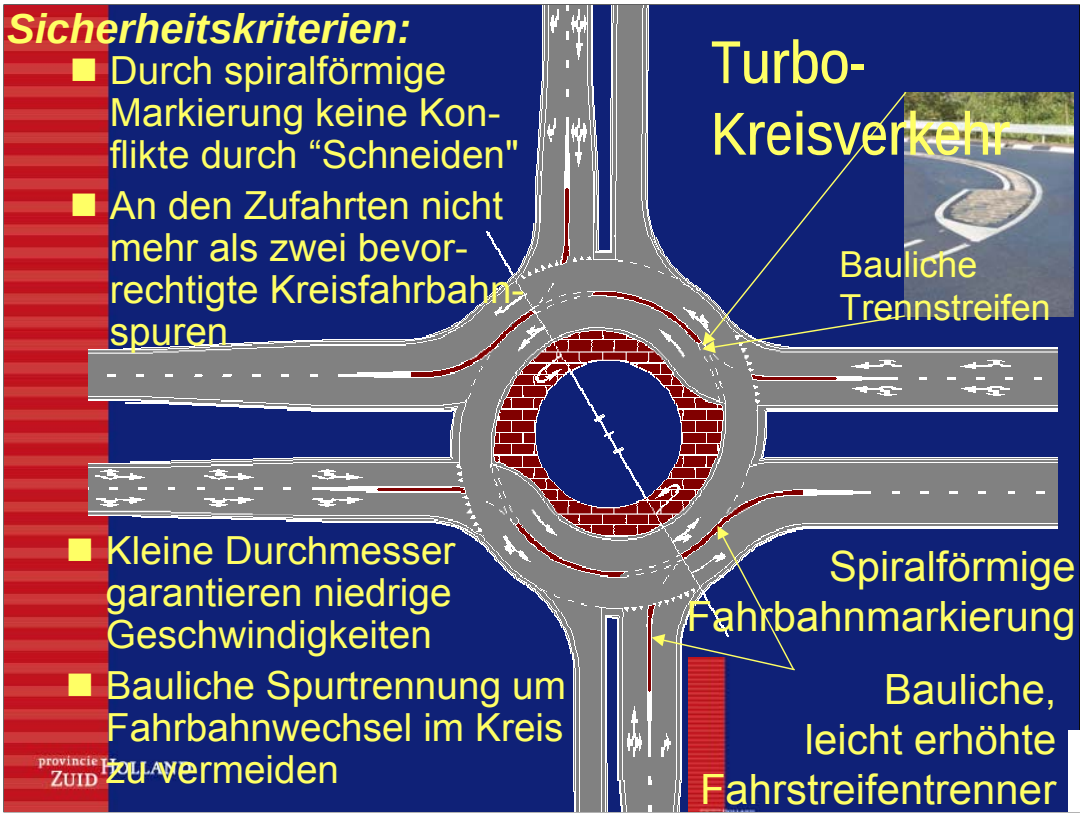
-By applying circles with variable central points the vehicle tracks become smooth. The driving comfort is optimized by positioning the translation axis (that is the axis on which the different central point are positioned) in such a way that for all straight on going vehicles the deflection (and hence the speed) is about the same.

- Lanes have to be chosen so wide, that trucks of 16.5 m length can use the RA without having to use heightened aprons (correct curve widening for the circulatory roadway)

- By applying mountably raised aprons long trucks of 28 m with steerable back axles can also pass the RA.

-Last but not least:

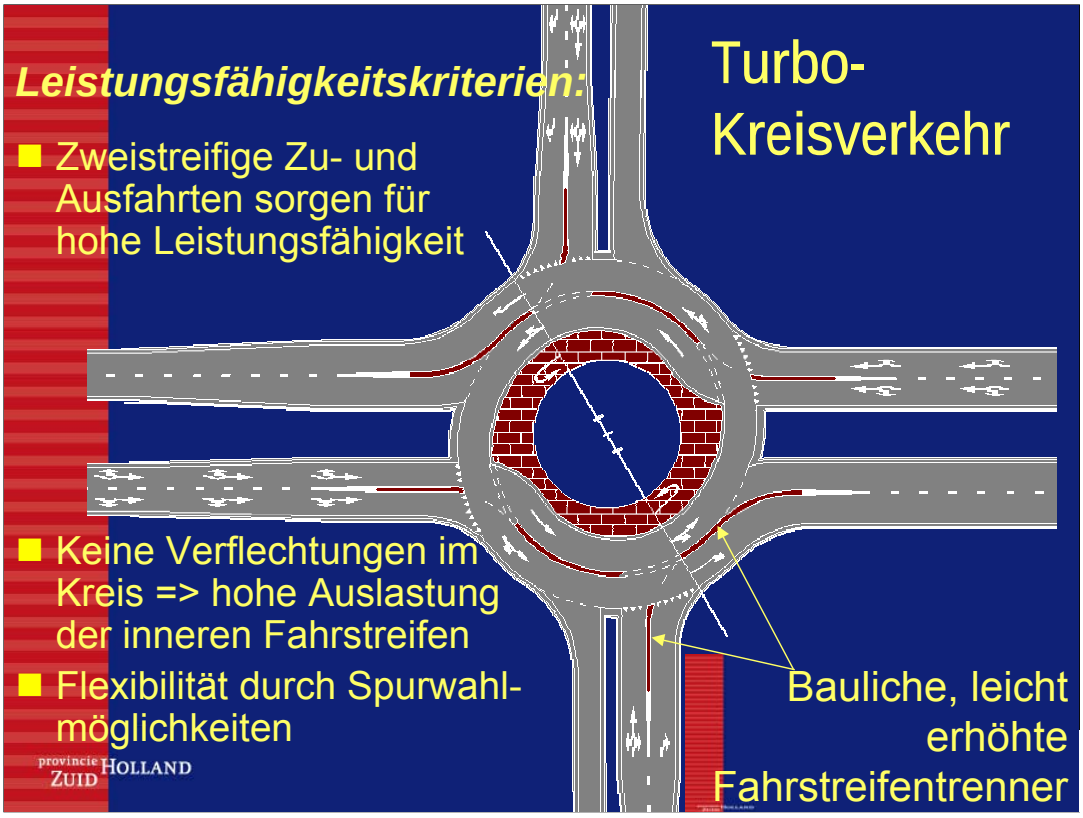
Route signing, road markings and lane information must be consistent and offer the driver approaching the RA optimal information to choose the right lane,



Implementing safety characteristics in the design

The safety characteristics are:

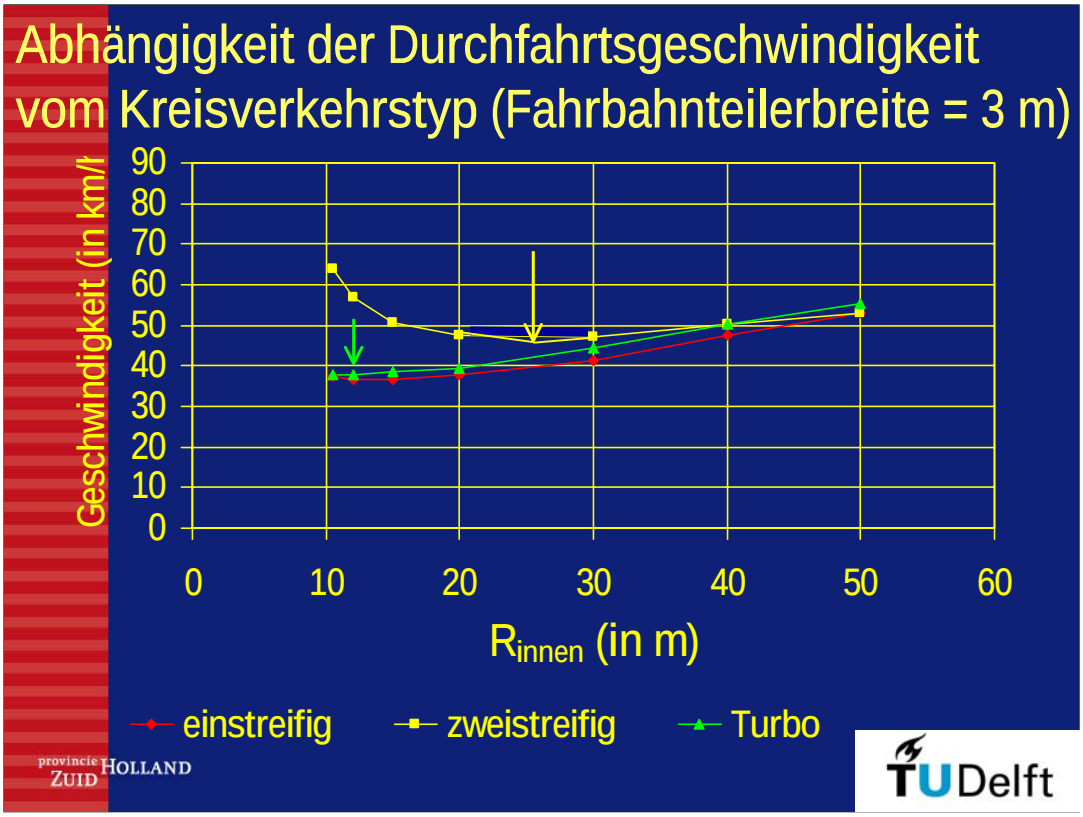
- No cut-off conflicts by using spiral striping
- No more than 2 continuing lanes at the RA
- Guaranteeing low speeds at the RA by using a small diameter
- Prevent cutting off of lanes by physical lane separations at the RA
- Apply a good relation between the widths of the splitter islands in connected branches and RA radii, in order to reduce the speed of through going vehicles sufficiently.



Implementing capacity characteristics in the design

- By using 2 entrance and 2 exit lanes a high capacity is obtained
- No weaving on the RA and consequently a well used inner lane
- By offering lane choice to the drivers different demand patterns can be handled

Since 2000 about 40 roundabouts of this type have been built in the Netherlands.



Relationship between Pass Through Speed and Type of Roundabout (width of splitter island=3 m)

(1) This graph shows the relationship between the **pass through speed** *(vertically)* and the inner radius *(horizontally)* of several types of roundabouts.

Red: the single lane roundabout

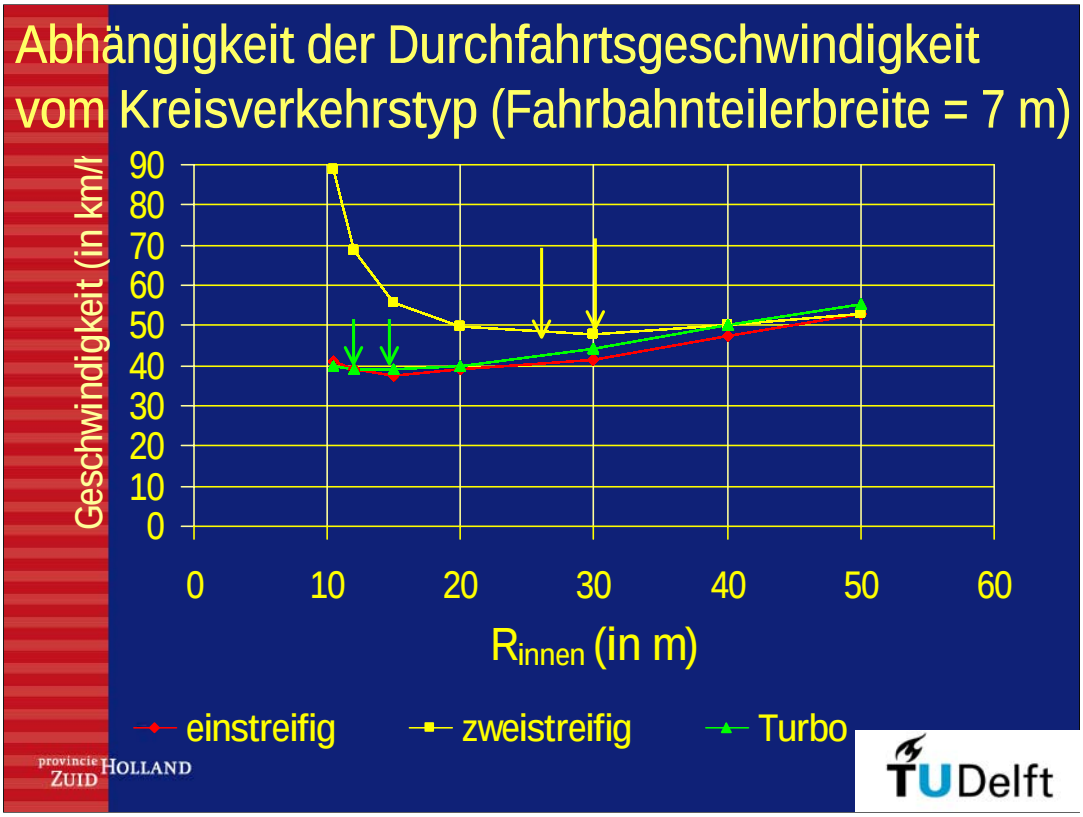
Yellow: the double lane roundabout without lane-dividers

Green: the turbo roundabout with lane-dividers

The impact of lane-dividers is obvious.

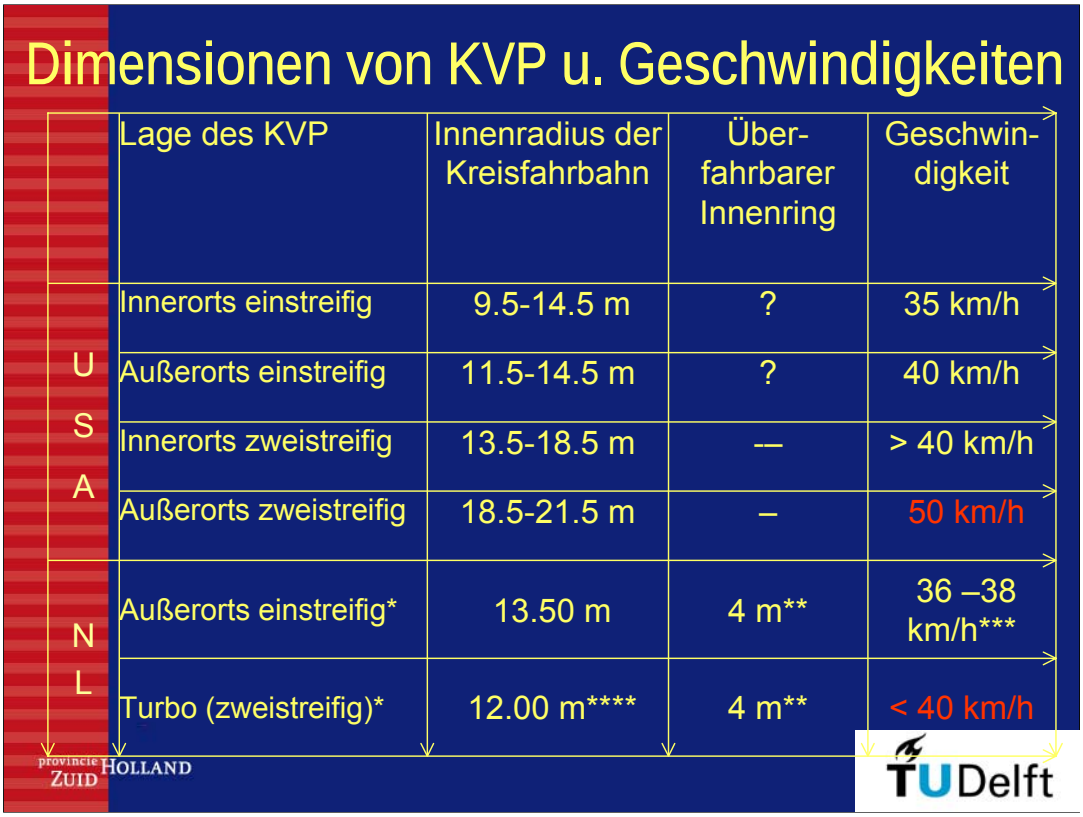
(2) Without lane dividers the minimum pass through speed on double-lane roundabouts is reached by a radius of 30 meters at a level of 48 km/h (30 mph)

(3) At turbo roundabouts, you need a smaller radius and the speed reduction looks like the reduction on a rural single lane roundabout - at a level of 38 km an hour.



Relationship between Pass Through Speed and Type of Roundabout (width of splitter island=7 m)

When the width of the splitter island in the legs are 7 meters, the minimum speed will be reached with a larger radius at a higher level

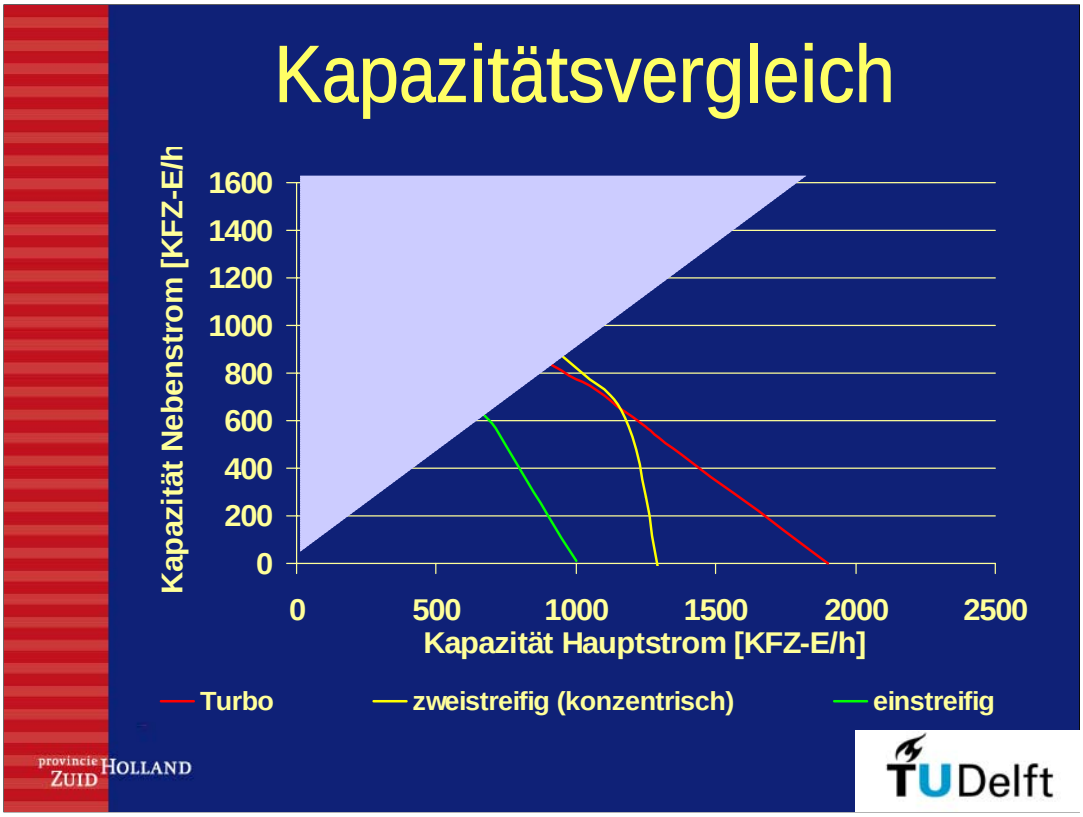


Dimensions for Roundabouts and pass through speed

This table shows the differences of measurements and the result in the pass through speed of different types of roundabouts in America and the Netherlands.

The speed on the American double lane roundabout is about 50 km/h, rather the same as we found in our graphs. Notice that the speed on the turbo roundabouts below 40 km/h.

And you remember: speed reduction at points of conflict is one of the most important elements to realize a safe traffic system.



Capacity comparison

Horizontally: you see the intensity of the most loaded leg (of the main road) in the approaching direction
Vertically: the entering capacity of the minor leg.

Calculations are for 4-leg roundabouts with a fixed split over destinations.

Evidently the turbo roundabout has a higher capacity than the concentric 2-lane roundabout when the main stream is dominant.

You see here the results of earlier calculations with the model “multilane roundabout explorer”. Meanwhile the model has been calibrated for only one RA. We think that the model probably was too optimistic. We found that the benefit of a more balanced use of the two RA lanes had been over-estimated.

We assume that in the case of a dominant main stream the bunching was less than expected, so there were less usable gaps in the two streams.

Two possible reasons can be distinguished:

- It is an inherent property of a dominant main stream;
- In the test site there was a lack of left turn traffic in the opposite direction.

Because we do not know the effect of the second possibility we changed the parameters according to the first hypothesis [haipòthesis].

Consequently the model now possibly underestimates capacity. (For a design this is not a drawback!)

However, also with the new parameters the Turbo RA is better in cases with a dominant main stream.

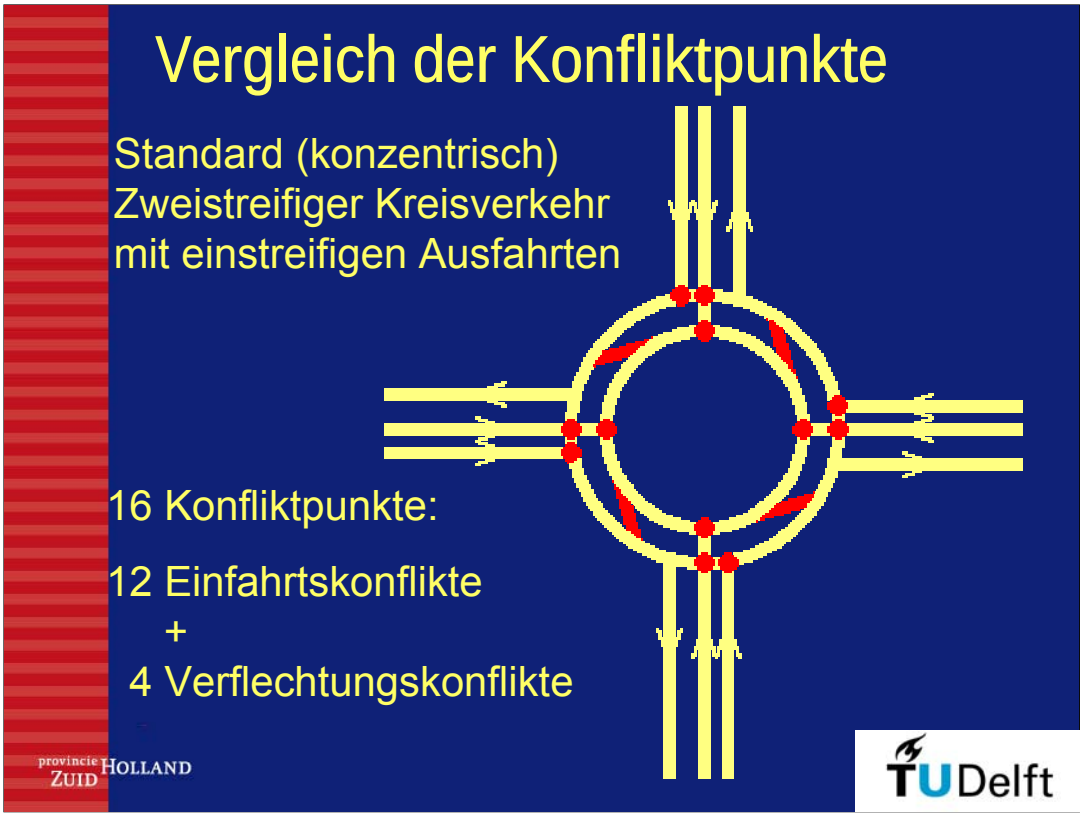
Of course the intention is to improve the model by more observations and simulations.

Conflict-Points at Two-Lane Roundabout with Concentric Road Markings

This picture shows the possible conflicts on a 2-lane RA with 2 exits with double lanes.

Different types of conflicts have been distinguished in this picture.

Next pictures show these conflicts more schematically.(ski:meitikeli)



Conflict-Points TWO-LANE RA WITH ONE-LANE EXITS

Here you see the conflicts on a standard concentric TWO-LANE RA WITH ONE-LANE EXITS

12 Entrance conflicts +4 weaving conflicts

Legend

Point: *entrance conflict*

Line *weaving conflict*

Conflict-Points on a concentricTW0-LANE RA WITH 2 DOUBLE LANE EXITS

This picture shows the CONFLICTS ON A concentricTW0-LANE RA WITH 2 DOUBLE LANE EXITS, comparable with the standard Turbo RA

12 Entrance conflicts + 2 weaving conflicts + 2 cut-off conflicts

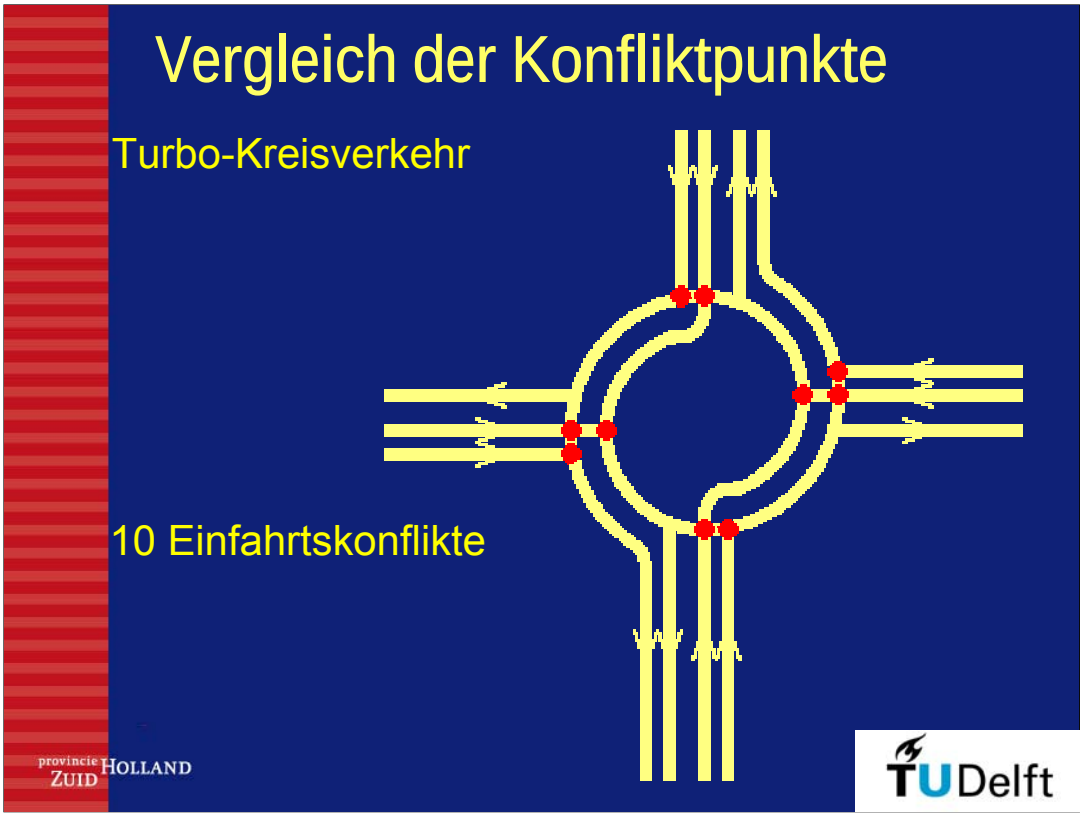
Legend

Point: *conflict point*

Line: *weaving conflict*

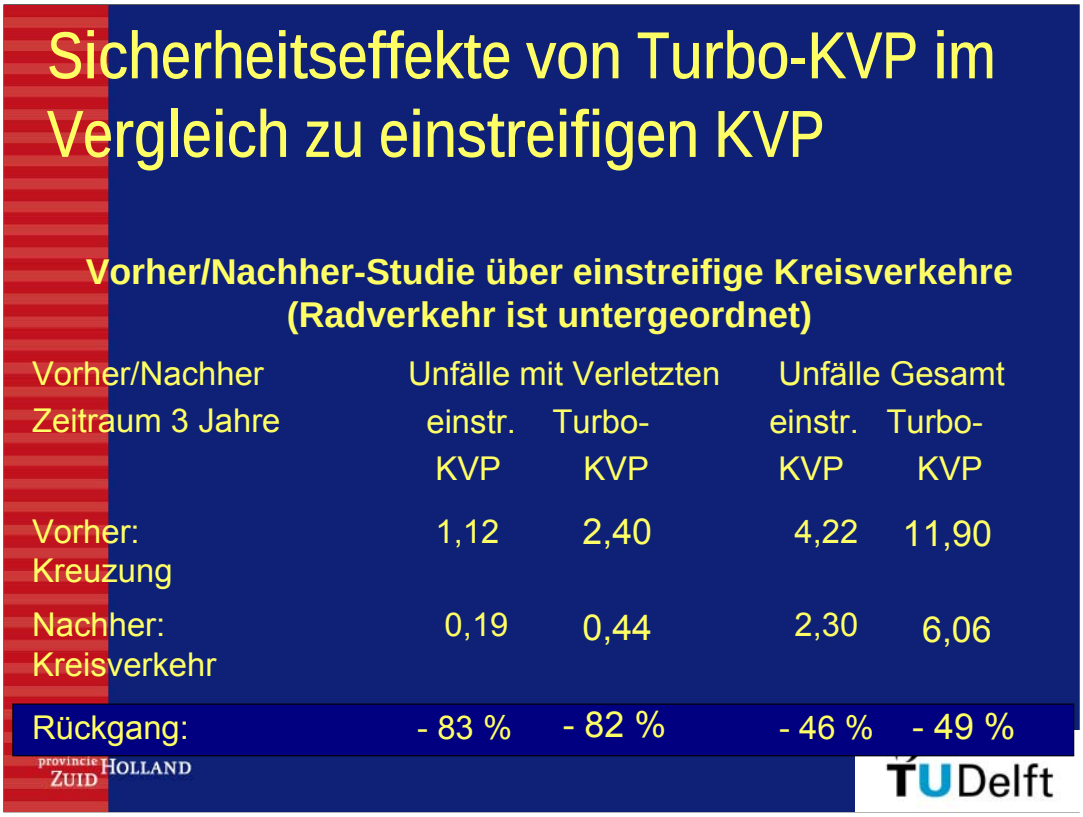
Cross: *cutting-off conflict*

.



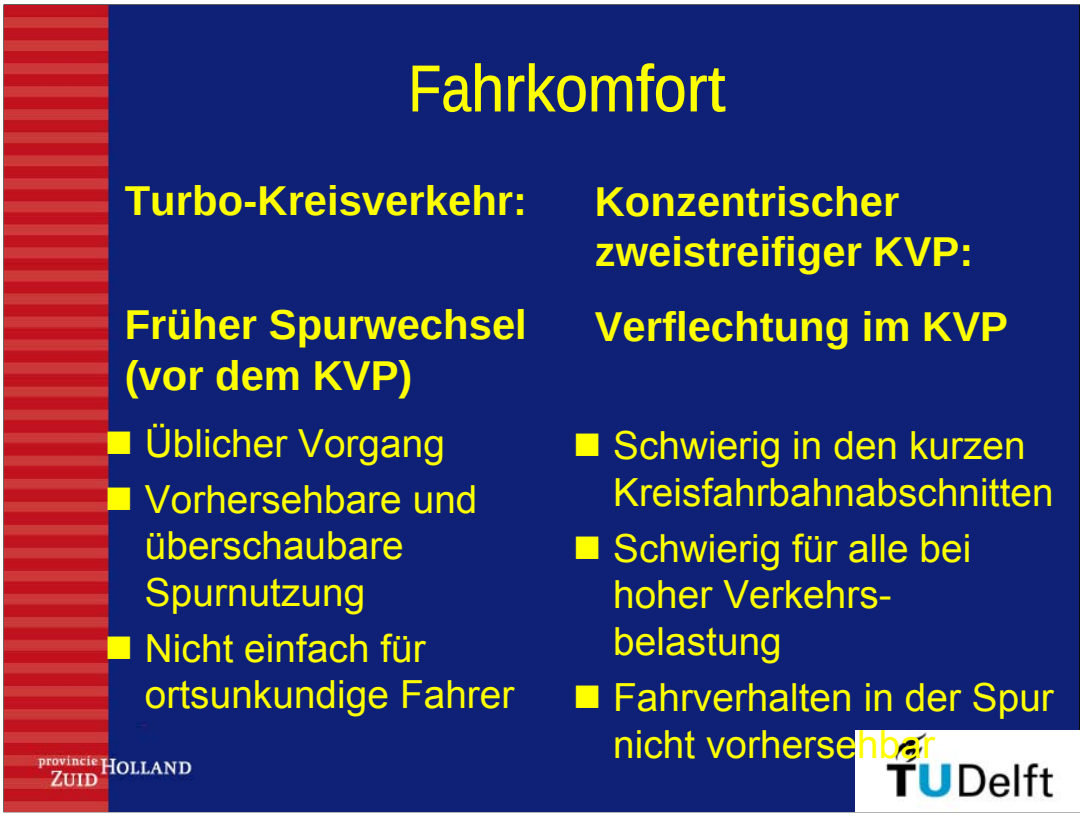
CONFLICTS ON A TURBO RA

A turbo RA has 10 conflict points, and, no weaving conflicts and no cut-off conflicts are possible



Effect on safety of the building of Turbo Roundabouts in comparison of Single-lane Roundabouts at spots of all kinds of intersections

It is remarkable, that the decrease of accidents for turbo-roundabouts is comparable with single-lane roundabouts.



Now the comparison of the point of Driving Comfort

The nice point for the drivers of a single lane RA is that he/she can choose the exit at the RA itself.

There is no need:

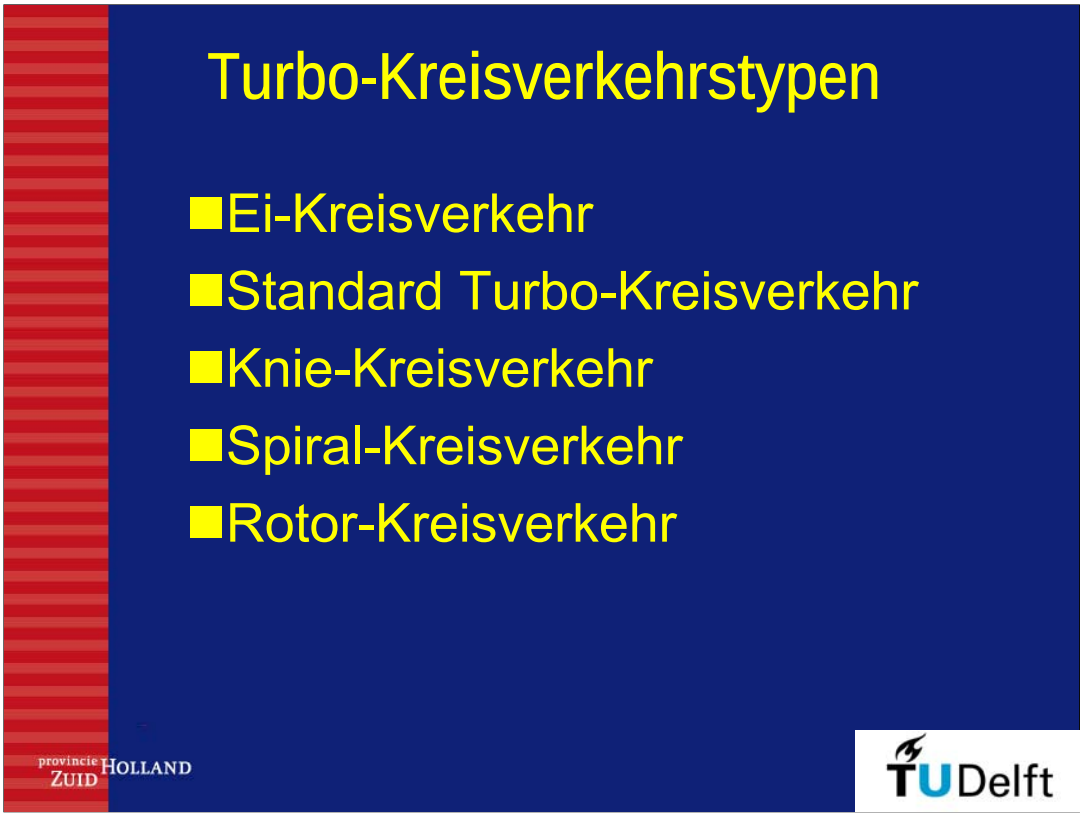
- to choose the right lane when being upstream (as is often the case at signalized intersections);
- to weave on the RA when deciding to leave it.

The problem with multi lane RA's is that a choice has to be made between 2 solutions:

- Up-stream lane choice and consequently no weaving on the RA (spiral striping)
- No obligatory up-stream lane choice and consequently allowing lane choice on the RA, with the disadvantage that the use of the inner lane always implies the necessity of weaving (concentric striping).

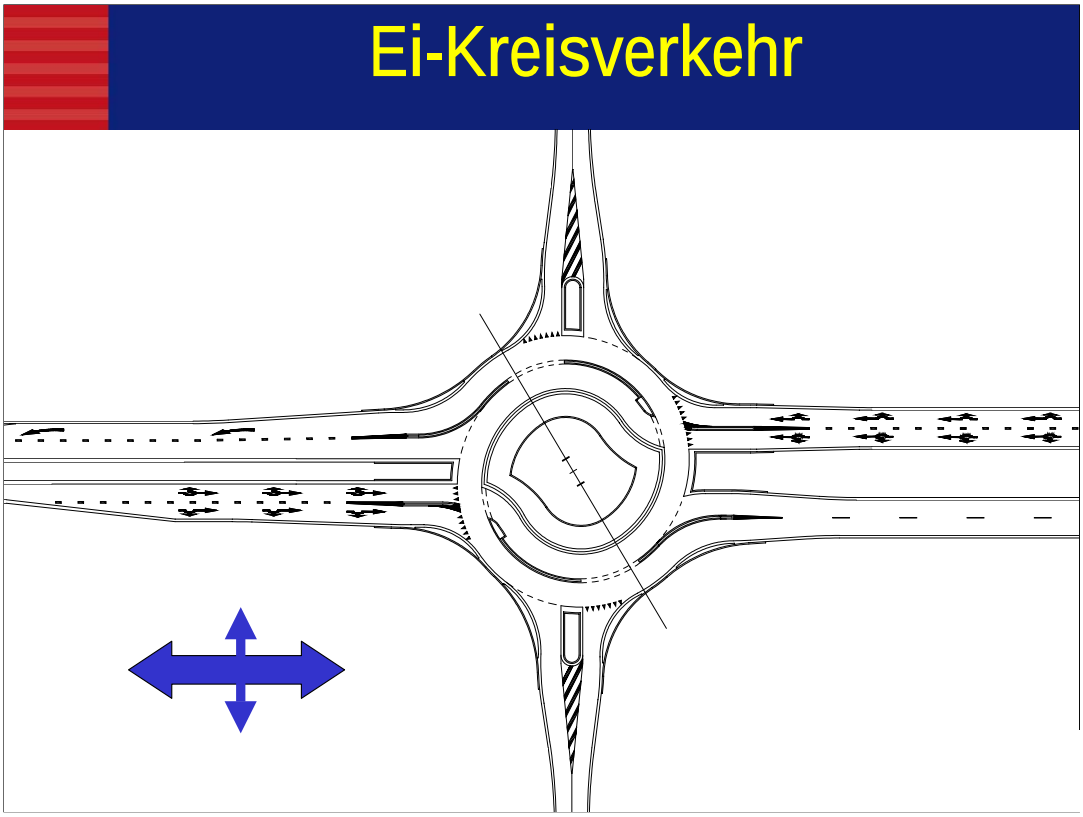
What are the advantages and disadvantages?

(Sheet)



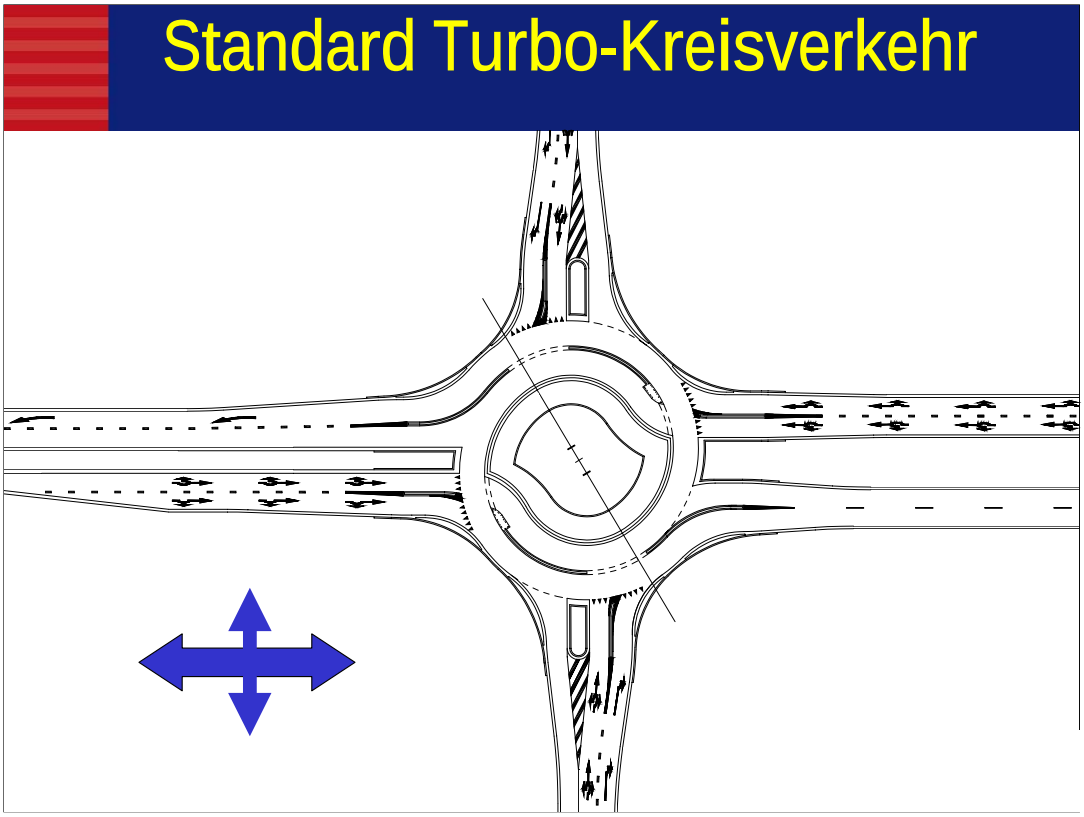
Types of Turbo-Roundabouts

The branches of a turbo RA can have a different number of lanes, leading to several different turbo RA's.
However, for all turbo types the same key design points hold.



The main characteristics of the Egg-RA are:
- Two double lane exits and two single lane exits;
- Two double lane entrances and two single lane entrances.

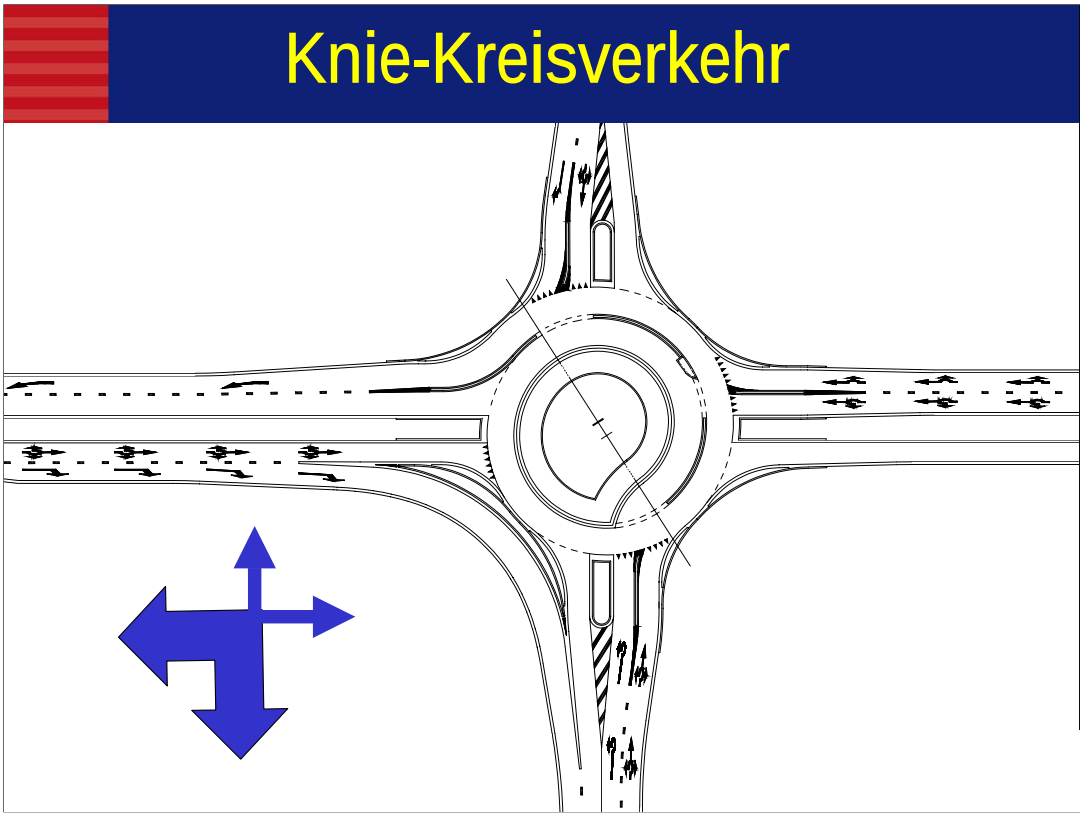
That makes this type of RA suitable for an intersection between
one road with a big through going flow
and the other having a relatively minor flow.



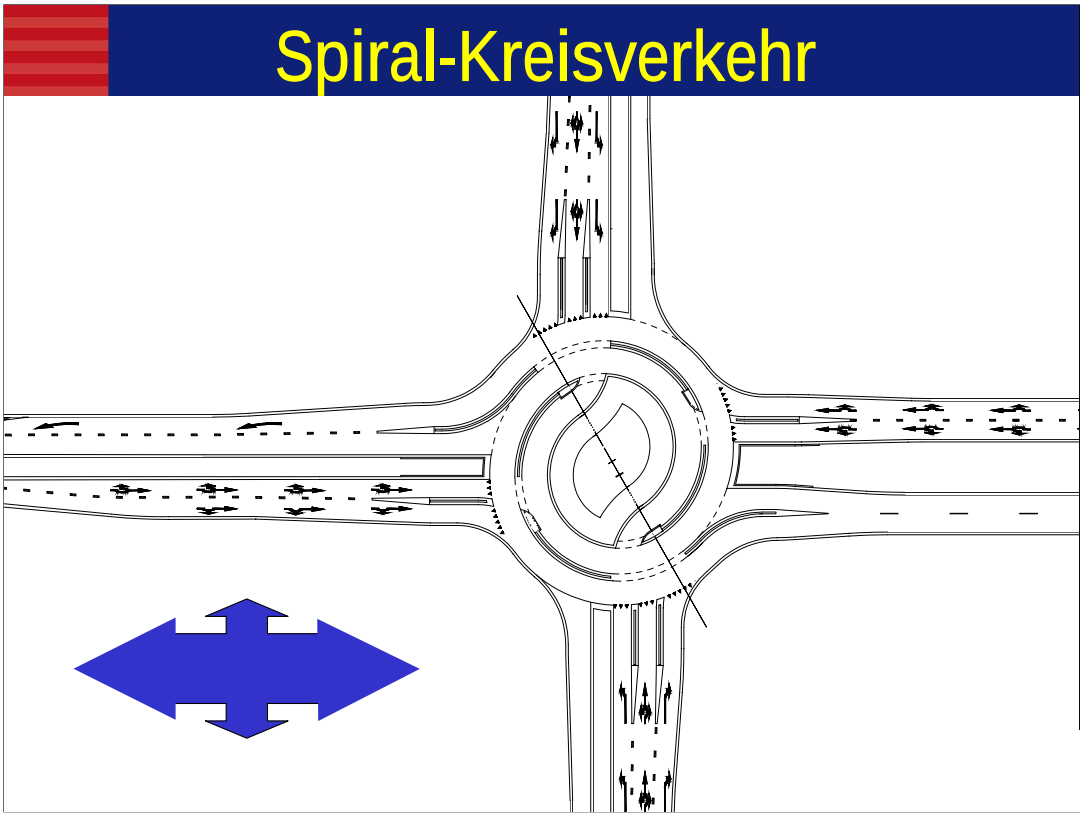
The main characteristics of the Basic Turbo-RA are:

- Two double lane exits and two single lane exits;
- Four double lane entrances.

That makes this type of RA suitable for an intersection between
one road with a big through going flow
and the other having a somewhat less flow.



The Knee-RA is suitable for an intersection with a dominant stream that largely goes left and right, as indicated.

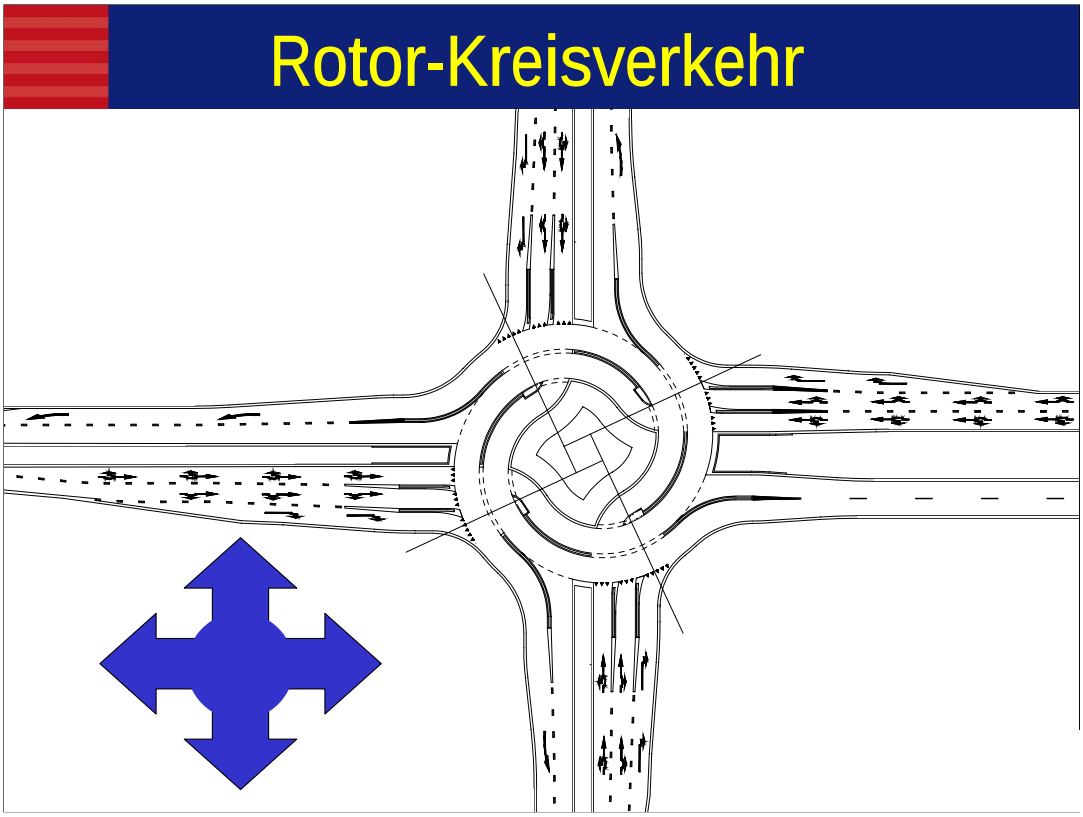


The main characteristics of the Spiral-RA are:

- Two double lane exits and two single lane exits;
- Two three lane entrances and two double lane entrances.

That makes this type of RA suitable for an intersection between
one road with a big through going flow
and the other having a flow mainly going left and right.

NB How about AM-peak and PM-peak; if they are reverse in direction,this pattern is not possible!



The main characteristics of the Rotor-RA are:

- Four double lane exits;
- Four three lane entrances;
- Possibility to turn right via two lanes;
- Possibility to go straight on via two lanes;
- Possibility to turn left via one lane.

The last point implies that the Rotor RA does not always have the highest capacity. Unfortunately it is not possible to turn left from all directions via two lanes; that would require 3 lanes on the RA in stead of 2 (and that is in conflict with the key principles of the design)

DEVELOPMENT OF BONE -RA

Starting point of the design process has been a solution with 2 single lane RA's.

That would have been a standard solution.

However, looking more precisely it it found that in this first solution 2 connections are hardly used.

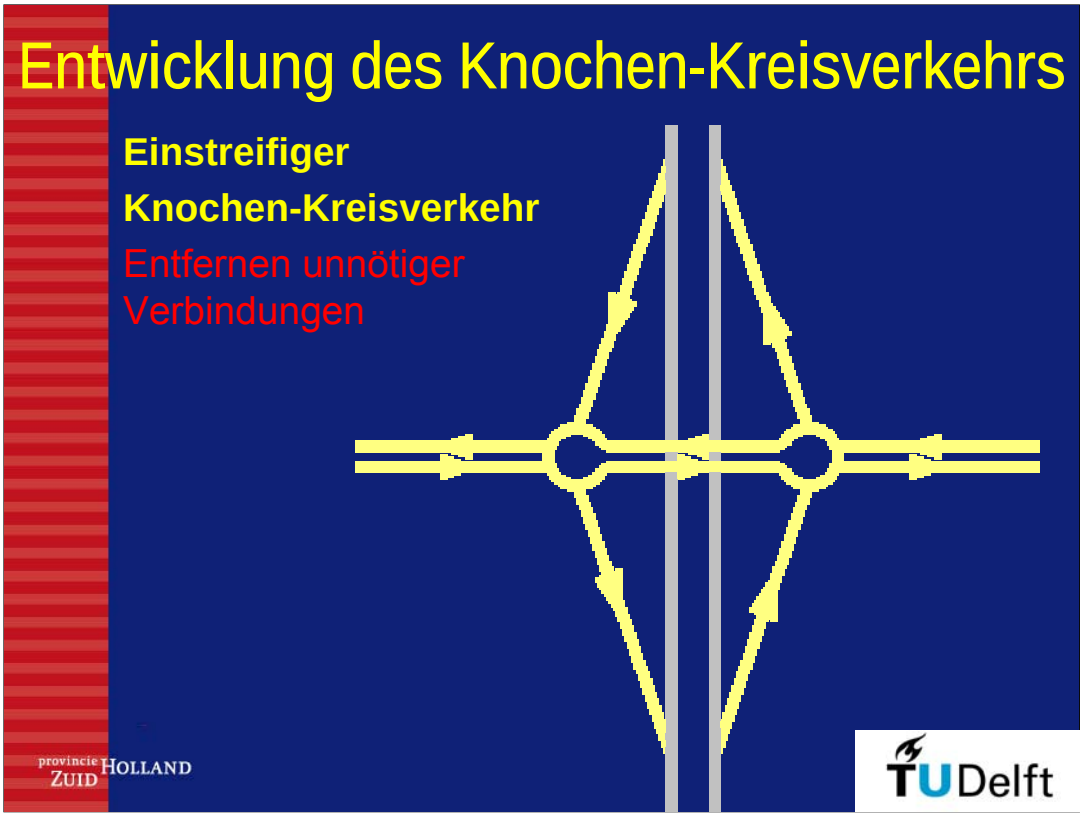
Explanation

Suppose a vehicle goes from west to north. It will never use the left shortcut. Suppose it goes from north to east; again it does not use a short cut. This holds for all possible combinations.

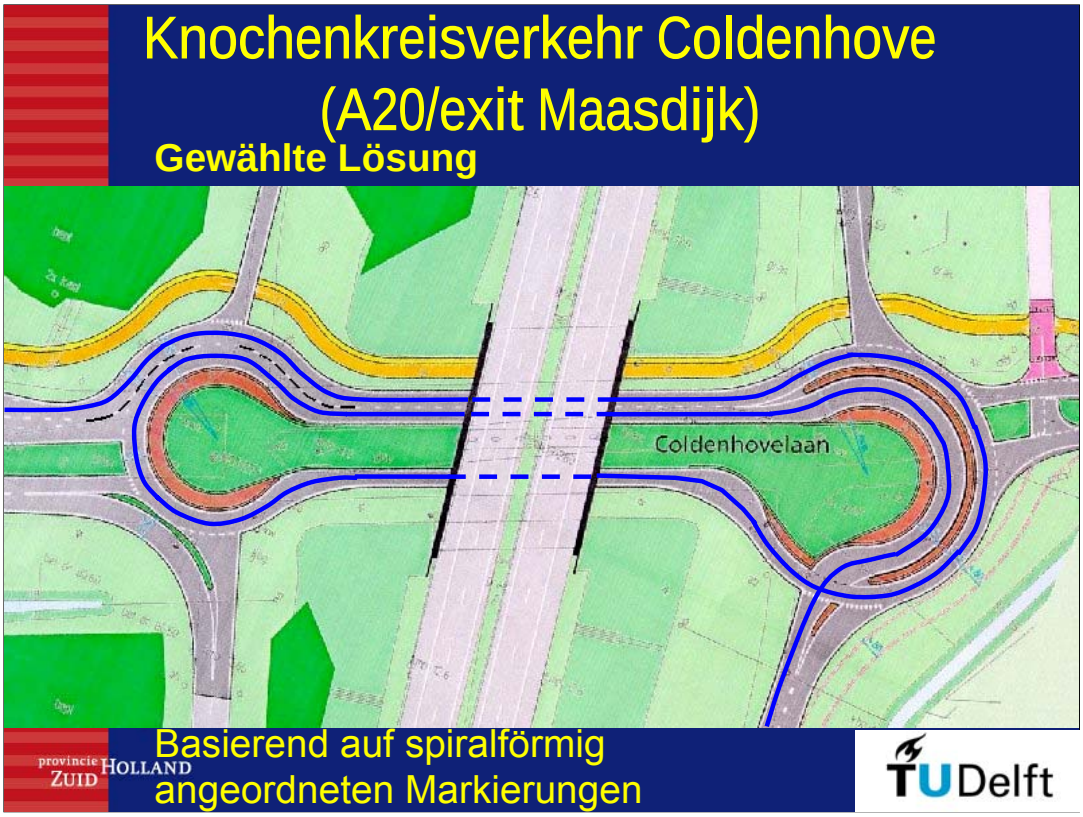
Also a driver taking the off ramp erroneously and wants to proceed via the on ramp does not need the short cuts; the same is true for a driver using off ramp and on ramp to make a change of direction on the motorway.

Only drivers coming from east and west using the RA as a turning point would use the short cuts. However, their number will be very small and that constitutes a danger. All regular users might be inclined to neglect this possibility and forget to give priority.

Also dropping the shortcuts decreases the likelihood of using an off ramp to enter the motorway (ghost driving) because a driver meets the “right” on ramp first.



Consequently the two short cuts can be left out.



Bone-RA Coldenhove The first Turbo Bone-RA

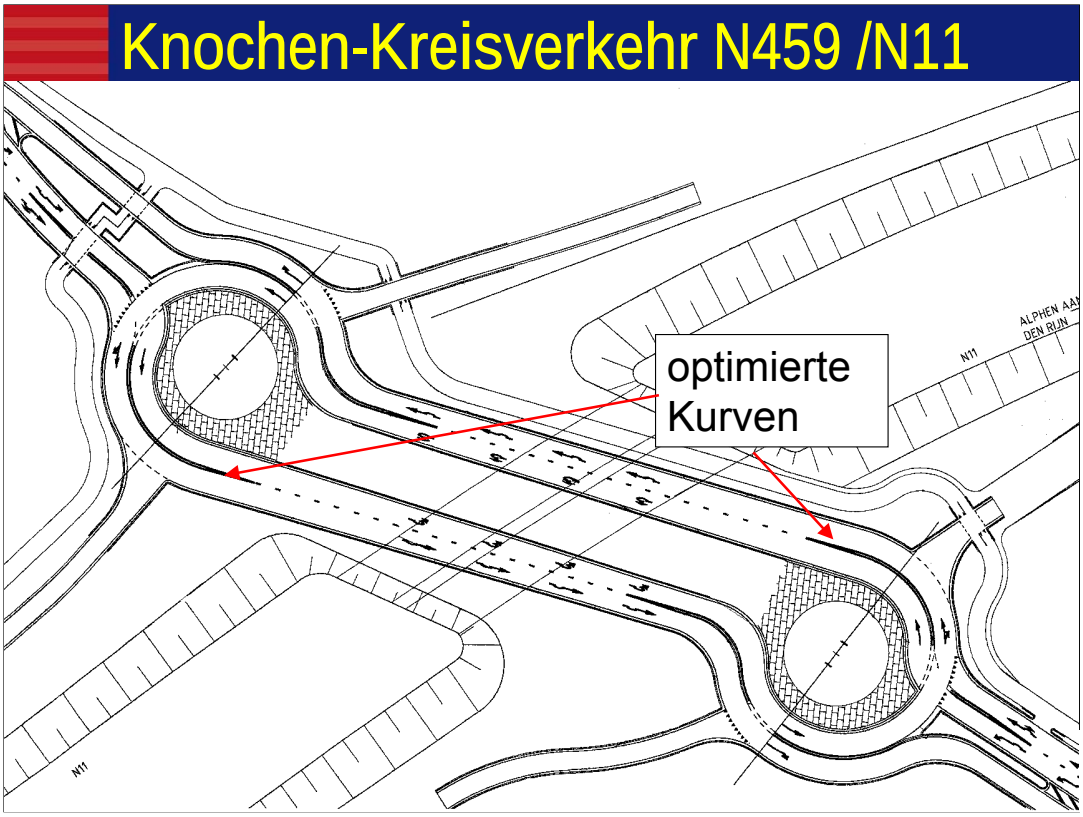
(intersection of main road N220 and motorway A20)

Note: the Bone RA development preceded the Turbo RA.

At this site single lane RA's would not have had enough capacity. More lanes were needed. These were built in a special way to cope with the highest demand being South-West and reverse.

The design has been such that weaving over short distances in curves is not required.

This design has a hidden spiral striping: coming from the south a driver, with destination West) could choose the left lane of RA-1(situated east of motorway); turn at the RA-2 (situated west of the motorway); come to the right lane at RA-1;and leave the site at RA-2.



Bone (Turbo-)roundabout based on the Turbo concept with tangential exit branches towards the inner circuit

Since the first design the Bone concept has been some what adapted.

The goal has been to eliminate extra steering maneuvers.

You see the eliminated curves in the picture.

However, the design should still not have vehicle tracks allowing speeds over 40 km/h

Design Elements of Turbo-Roundabouts

The following elements need discussion:

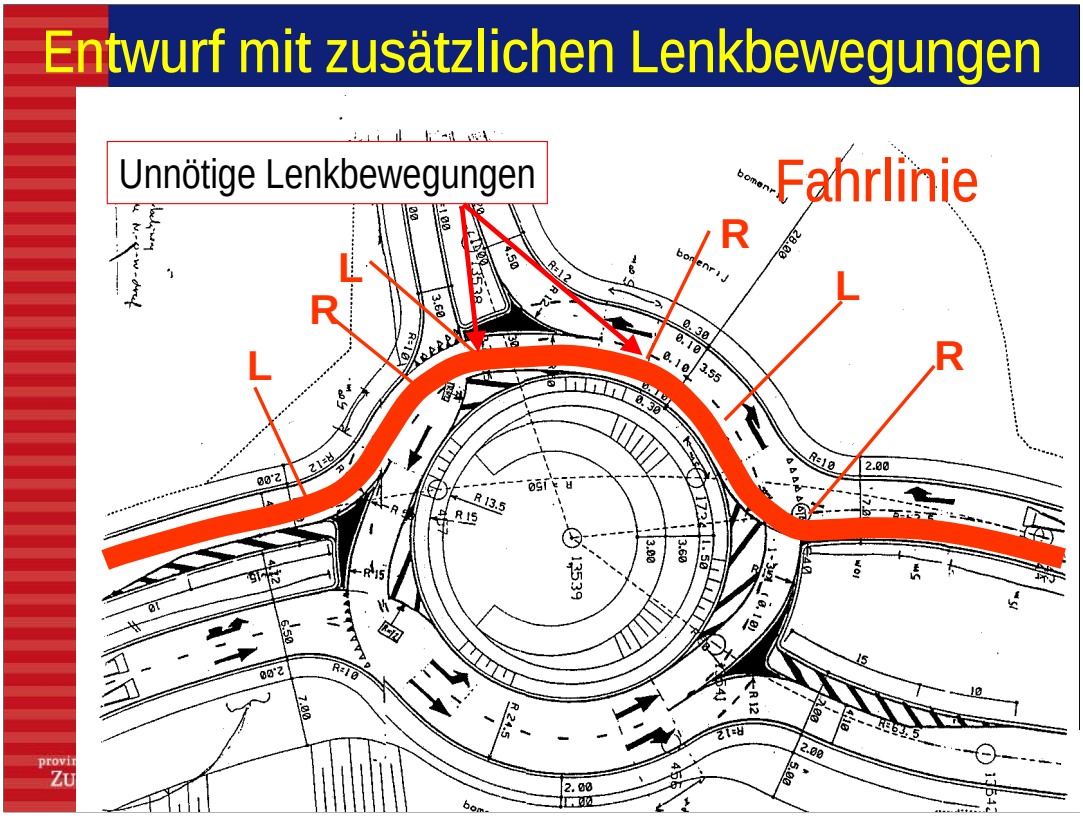
- Translation axis
- Raised mountable lane divider
- Directional arrow
- Sign posting
- Bicycle crossing

But we do not have enough time to do that. I will only mention that these elements are related to the fact that a Turbo RA:

- has a spiral striping (created by shifting center points along the so called translation axis)
- has small dimension (which as such promote safety, but) that invite the cutting off of curves (which is unsafe), which necessitates the use of mountable raised lane dividers.
- requires upstream lane choice (sign posting and directional arrows with lane choice signs)
- requires special facilities for bicycle crossings of 2-lane entrances and 2- lane exits;
- is a new traffic facility, of which some elements have not reached design maturity.

By exception I will deal with two elements:

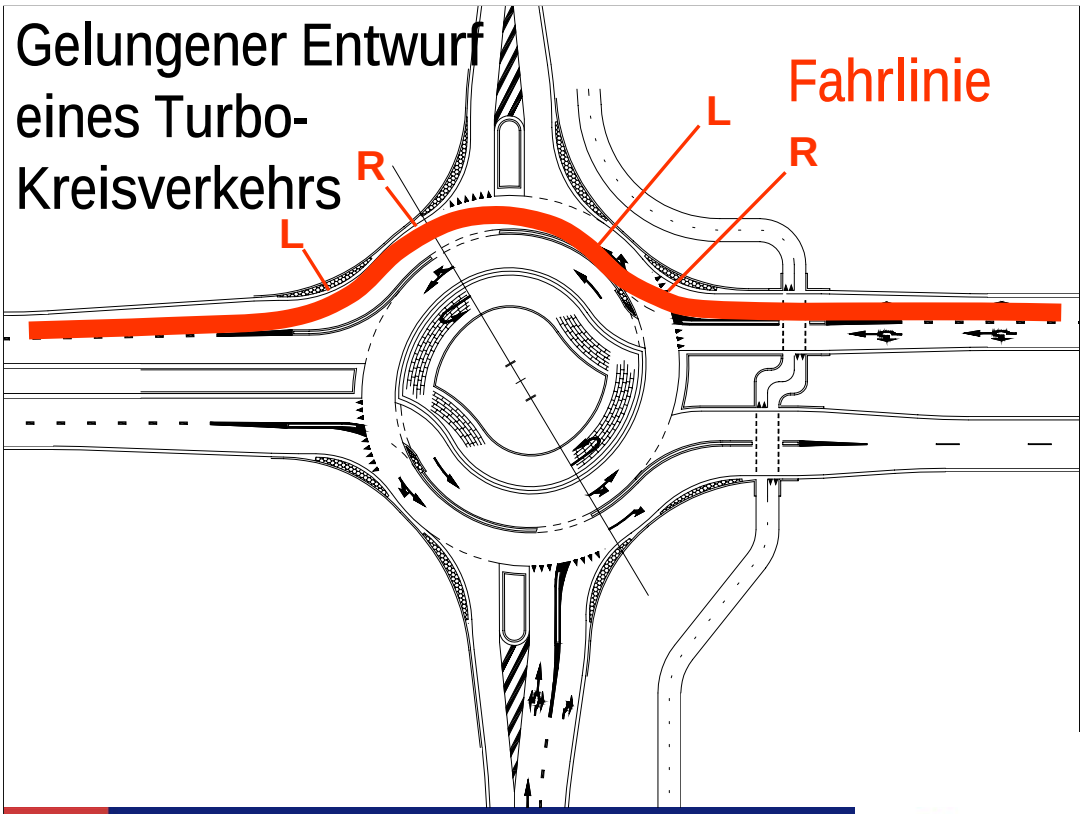
- the spiral tracing of the circulatory roadway (created by shifting center points along the so called translation axis);
- the raised mountable lane-divider



Drawing of RA "Noorderdreef-Oosterdreef" in Almere in which extra steering maneuvers are depicted. This design is acceptable if one rebuilds an existing RA (for financial reasons), but would be a bad design for a new RA.

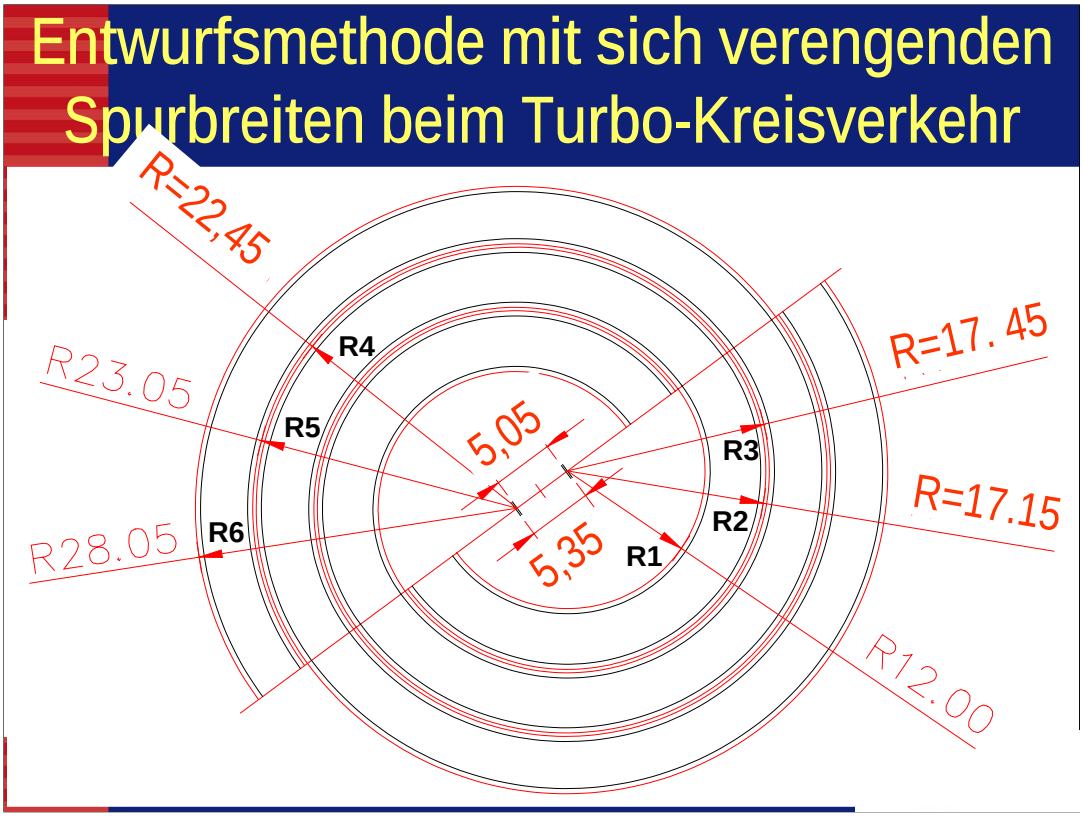
Geometric design with extra steering corrections

Applying a spiral striping on a circular RA leads to unnecessary discomfort for the drivers.
This design is acceptable if one rebuilds an existing RA (for financial reasons), but would be a bad design for a new RA.



Vehicle Path Curve on a Turbo-Roundabout

In the design of the Turbo Roundabout a logical vehicle track has been obtained by a system of shifting circle points over a translation axis. As a result a driver negotiating the RA, after entering the Roundabout only has to steer to a larger curve radius before he leaves the Roundabout.



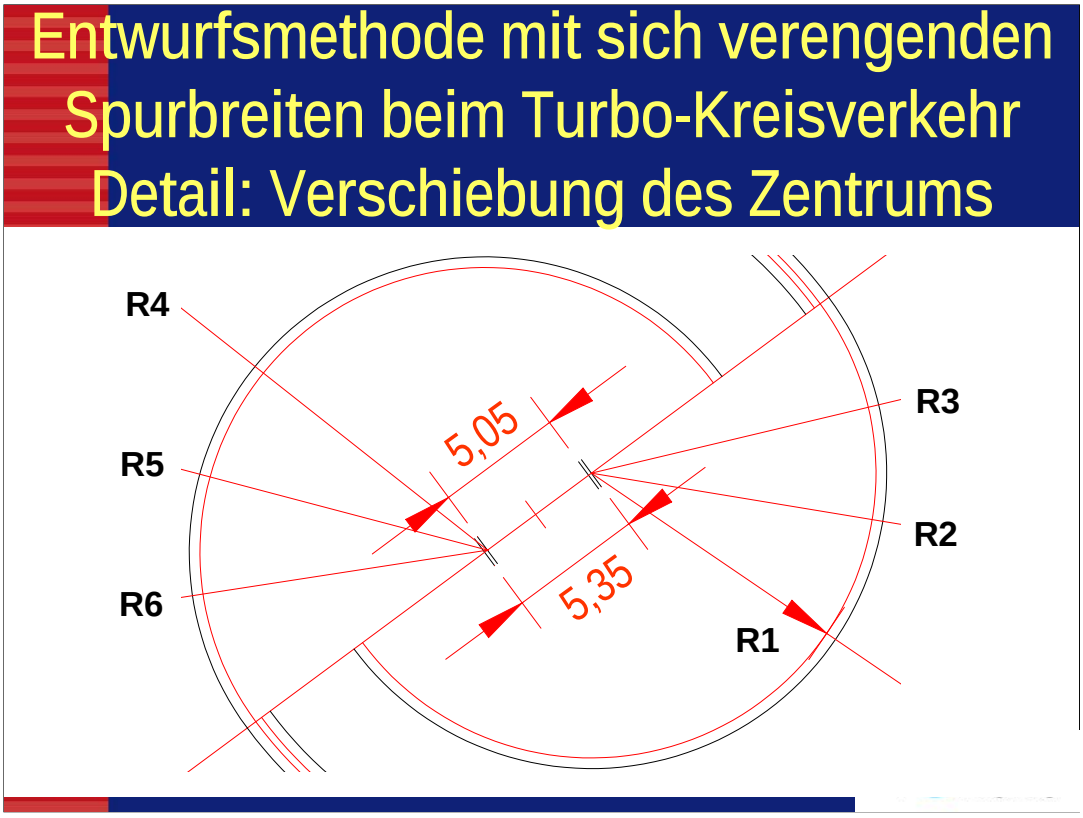
For that reason a design has been chosen in which circles with different center points cause the spiral striping.

The axis on which the center points are situated, is called the **translation axis.**

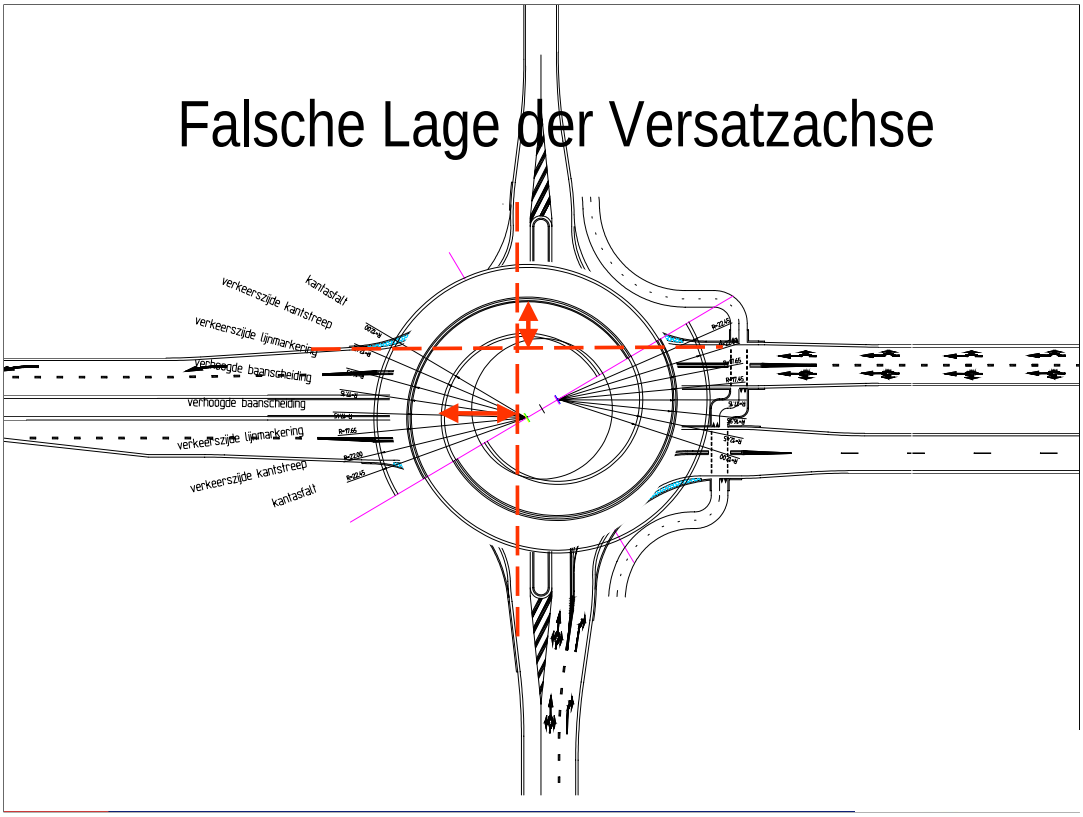
Here you see the turbo “roundabout block” in AutoCAD

It is possible to reduce the width of the carriage ways when the radius becomes larger.

This is illustrated above for the Turbo Roundabout.



In this drawing can be seen in detail how the center points shift.



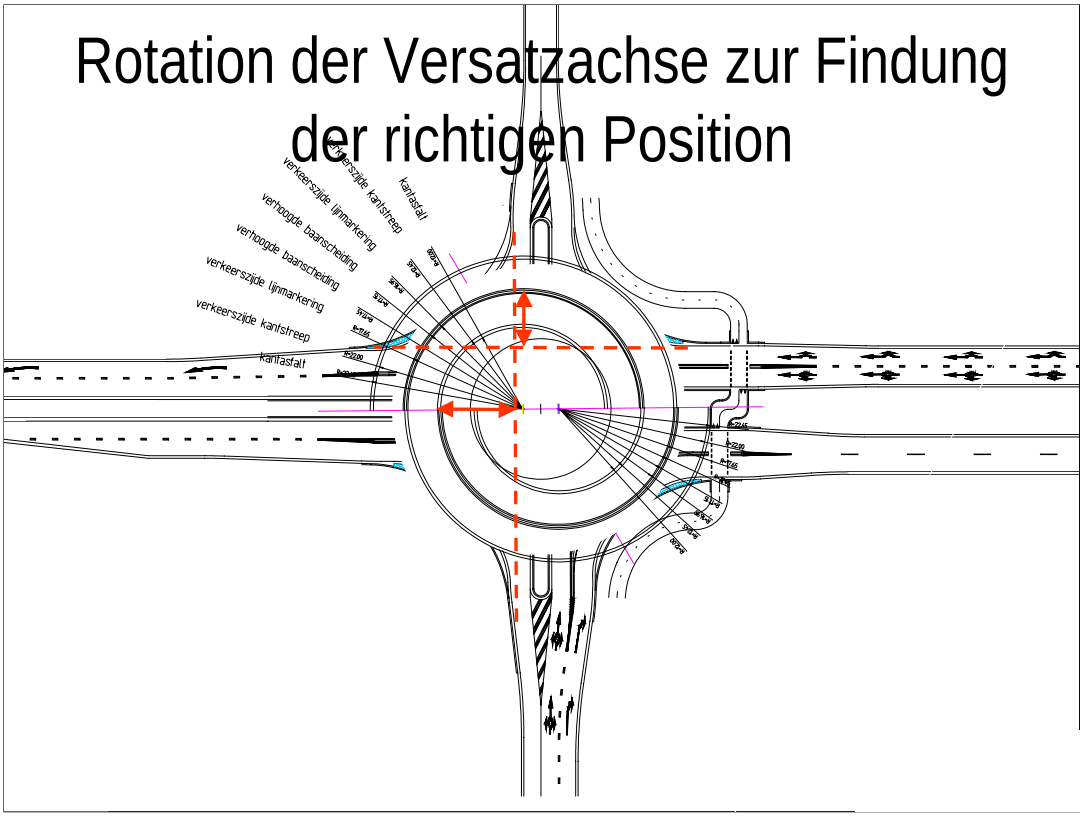
The position of the translation axis depends on several arguments.

First by the position of the double lane exits, in such a way that speed in all directions is about the same. That means, that the deviation of the vehicle track should be about the same in all directions.

In the drawing above the main road is horizontally and has double lane exits.

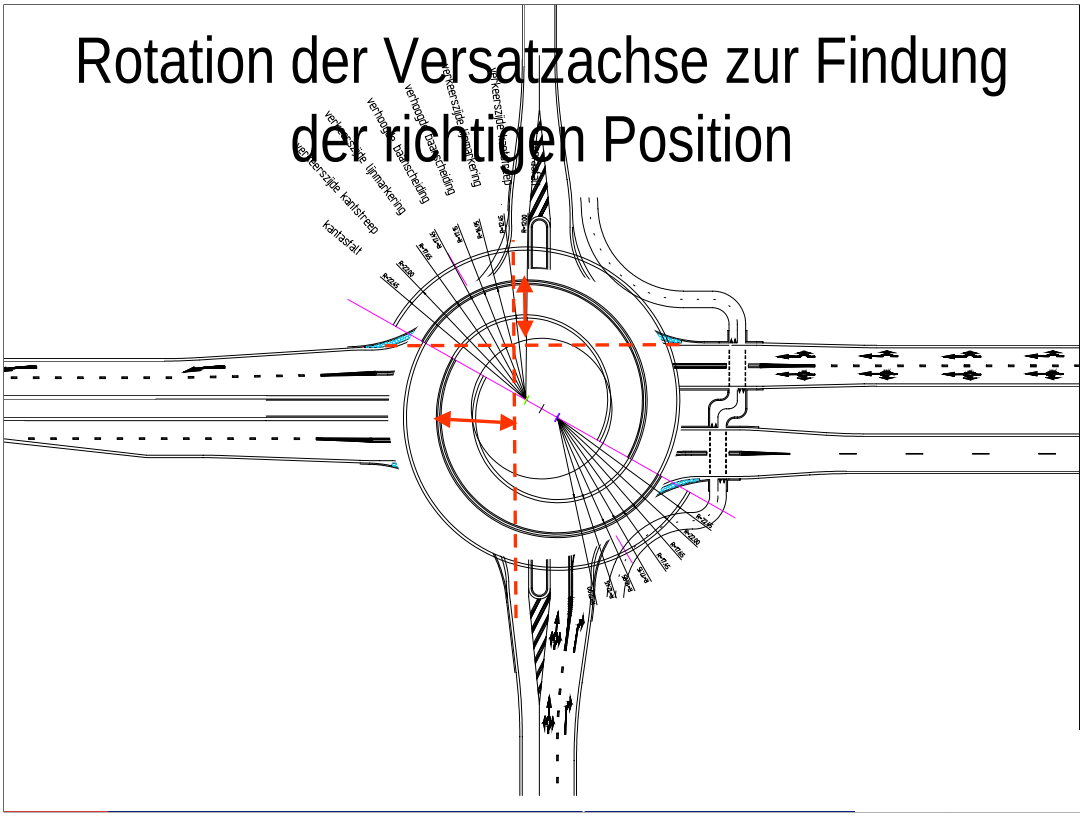
Therefore the distance to the center point of the outer horizontal exit lanes is larger than for the vertical exit lanes. But the goal is to make the deflection about the same in all directions.

We solve this by rotating the translation axis and the spiral lanes



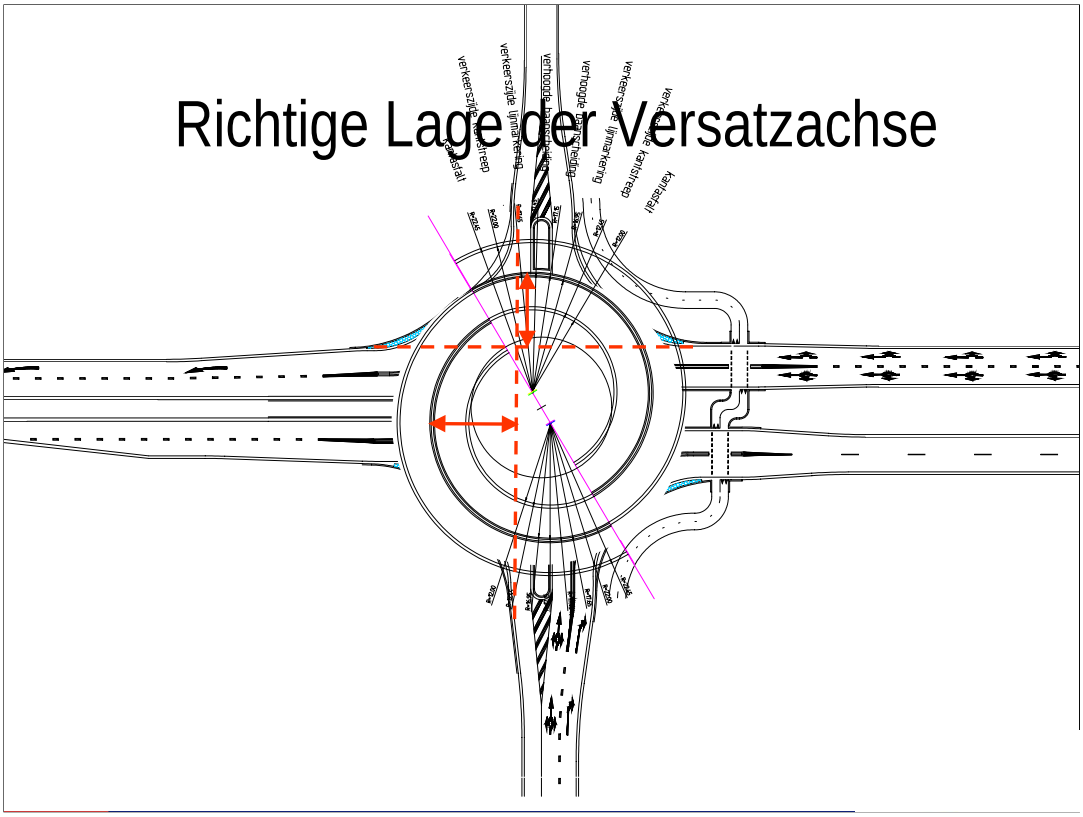
At this position of the translation axis, the deflection in direction North-South is still larger than in direction East-West.

Rotation der Versatzachse zur Findung der richtigen Position



Not yet optimal.

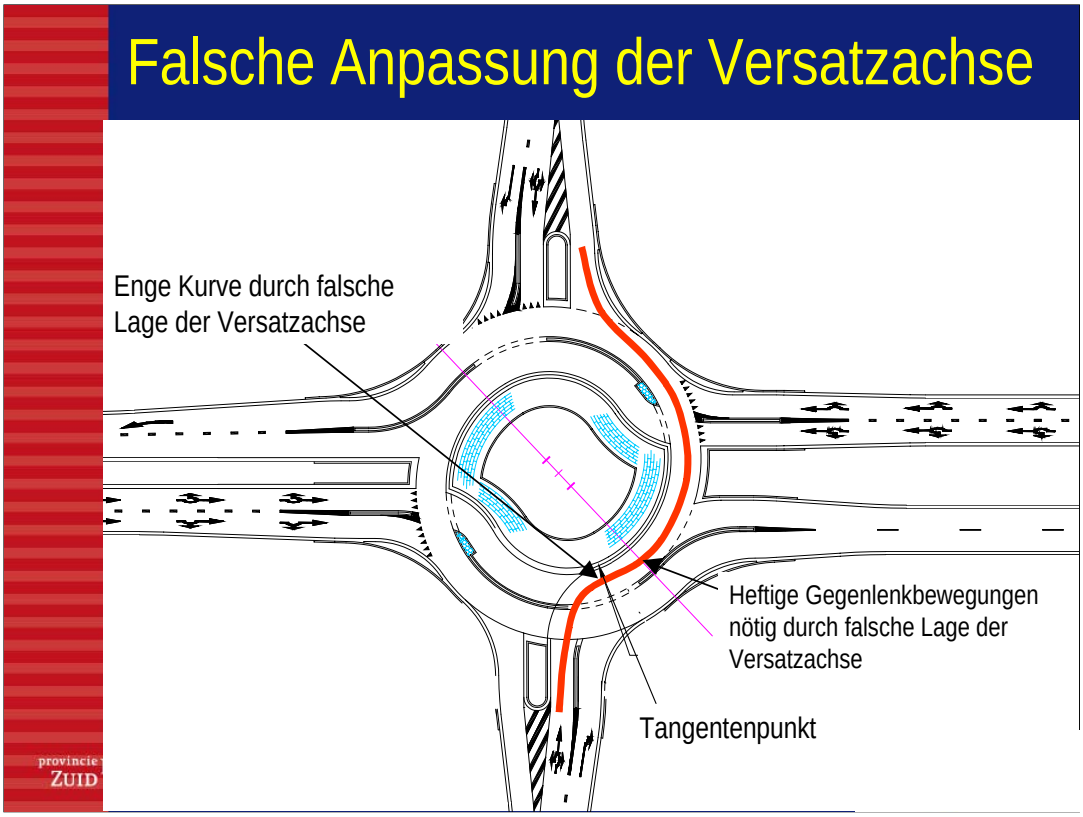
Richtige Lage der Versatzachse



With the translation axis in this position the deflections differ the least.

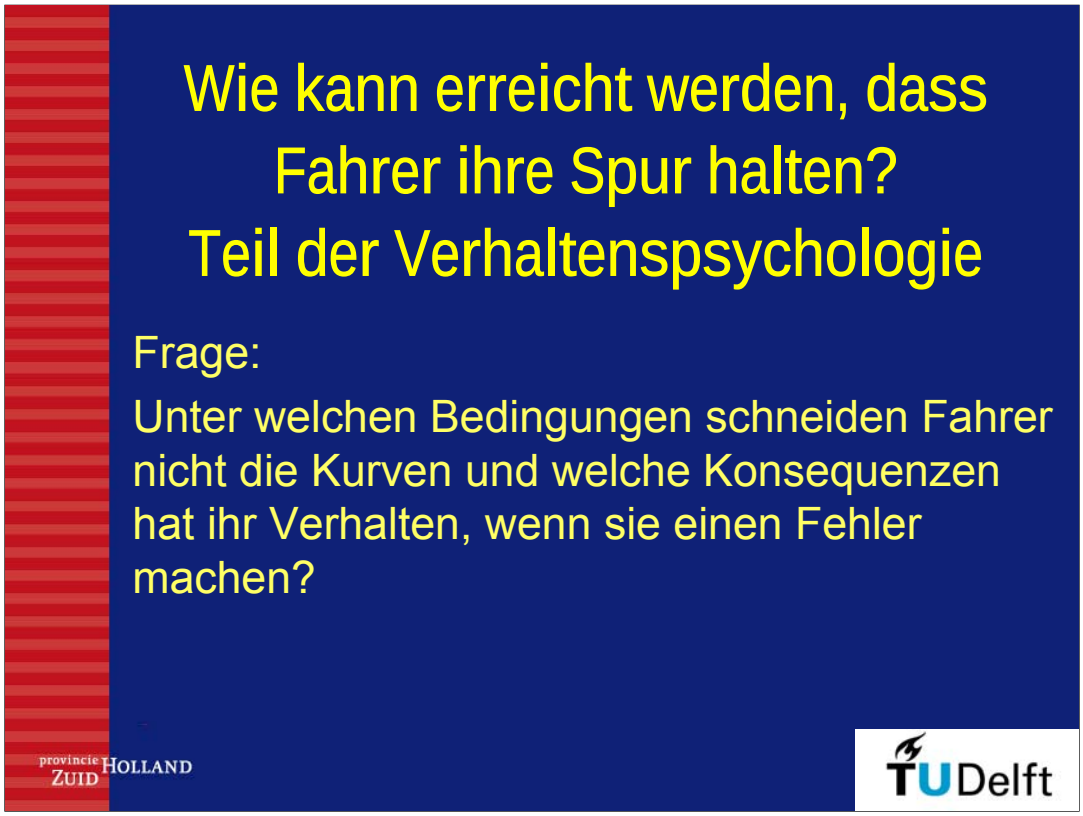
Secondly an other aspect has to be mentioned

If this axis in the depicted design would be turned a little bit anti clock wise (resulting in the intersection points with the RA lanes falling behind the tangent points), drivers from the south and the north should start steering sharply and immediate there after to a lesser degree. It is known that drivers do not appreciate that



After determining the global position of the translation axis, it should be fine tuned.

That means it should be checked that nowhere the intersection point of the translation axis with the RA curve should fall after the tangent point of the outside curb of the entry. Otherwise the steering angle at entrance will be sharp and immediately after that the driver has to apply 2 contrary steering maneuvers.



How to reach that drivers keep their lane?

What is the contribution of psychology [saikolədzi] into this matter?

By example the question: What are the conditions under which drivers will not cut off curves and what are the consequences of that behaviour when the driver makes a mistake?

Bauliche, leicht erhöhte Fahrstreifentrennung

Here you see a photo of a turbo roundabout with mountable raised lane dividers. You see the rear wheels of the truck can use the mountable lane divider.

Raised Mountable Lane Divider

Disadvantages:

- Because it is difficult to mount them, a wrong lane choice implies a detour.
- It is an obstacle which constitutes a danger

Advantages:

- Speeds become lower causing a large safety benefit
- Capacity increases because the inner lane is well used
- The use of lanes becomes more predictable and makes the entering of the RA easier

Concrete elements of 30 cm wide and 7 cm height have been applied.

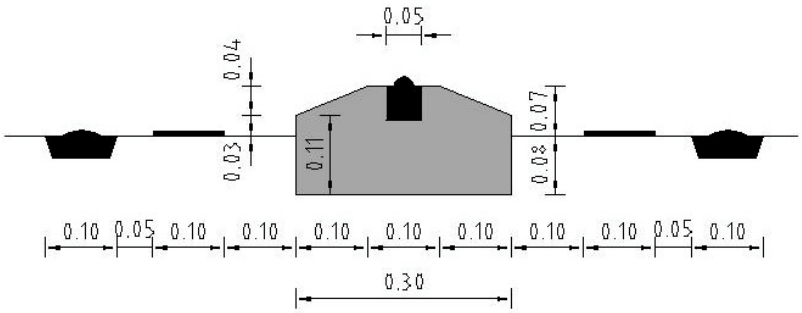
Possible problems:

- Strength of the elements; therefore we made them thicker and placed them on the bituminous under layer.
- Skidding risk for motorcycles

Point of attention (also considering liability aspects)

- Contrast
- Lighting and road reflectors
- Upstream driver information

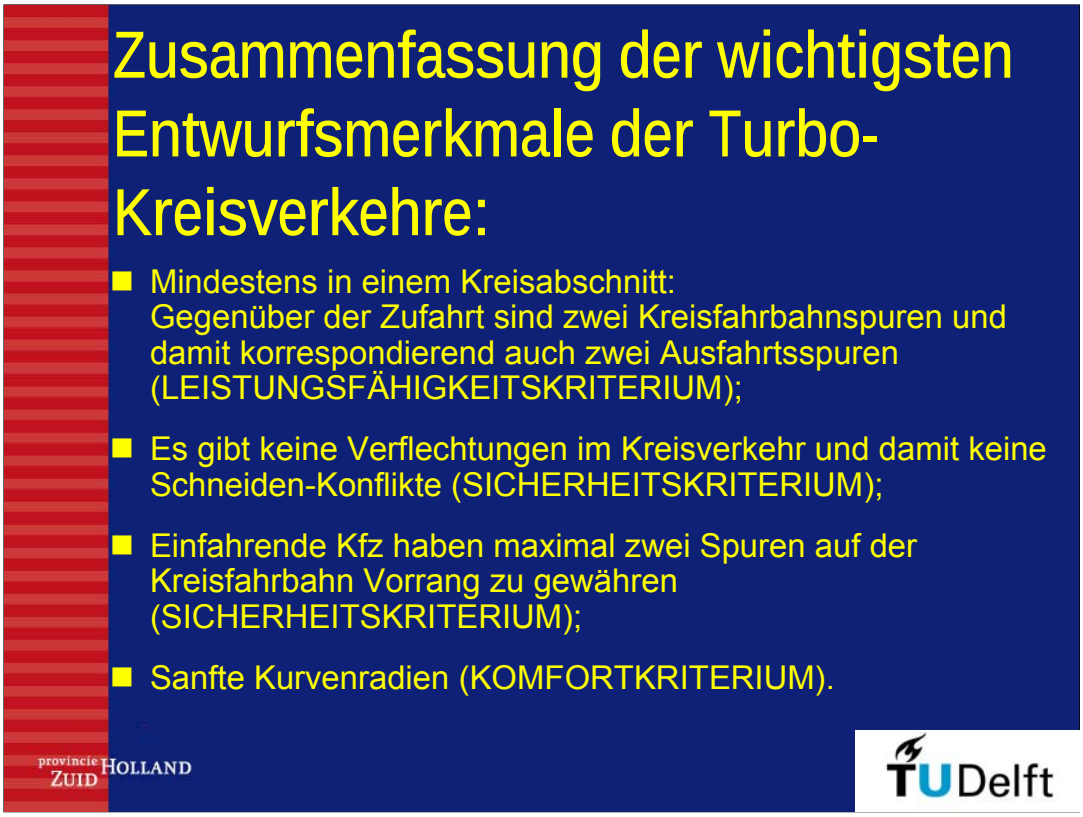
Bauliche, leicht erhöhte Fahrstreifentrenner



Detail: erhöhte, bauliche Spurtrennung

provincie ZUID

Here you see the raised mountable lane-divider in detail



Summary of Key Points in the Design

• At least at one (but it might be at 4) roundabout segment (opposite an entrance), there are two circulating lanes and corresponding with that, 2 exit lanes (capacity characteristic);
• No weaving at the RA and no cut-off conflicts (safety characteristic);
• Entering drivers have to give priority to no more than 2 lanes (safety characteristic);
• Smooth lane curves (comfort characteristic).