

Prevent right-turn accidents

Road and traffic engineering measures
in signalized intersections



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How to prevent accidents between right-turning lorries and cyclists going straight ahead in signalized intersections

Background and purpose

Denmark has a large number of cyclists. In Copenhagen alone, Danes cycle more than 1 million km every day. Consequently, the Danish Road Directorate works to ensure road safety, so that cyclists of all ages may navigate safely and feel safe among other road users.

This leaflet presents a number of road and traffic engineering measures for preventing right-turn accidents between lorries and cyclists. It should be seen as an inspiration for the local prevention of right-turn accidents and the improvement of safety for bicycles.

In March 2014, The Danish Minister for Transport published the "Strategy to prevent accidents between straight going bicycles and right turning lorries", which is the result of a collaboration between the Danish National Police, the Danish Transport and Construction Authority and the Danish Road Directorate.

Together with The Danish Road Standards, the strategy forms the basis for the recommendations in this leaflet. The primary purpose of the leaflet is thus

not to present new measures and new knowledge – many of the measures have already been fully detailed in the road standards – but rather to give an overall description of a number of road and traffic engineering measures that can contribute to preventing right-turn accidents both at a state level and at a municipal level.

Unless otherwise specifically mentioned, the recommended measures can also be expected to prevent right-turn accidents involving mopeds.

Most right-turn accidents are registered by the police as occurring between a normal passenger car and a bicycle, while the most severe ones usually occur between a lorry and a bicycle.

Approximately 25 % of all cyclists involved in accidents between right-turning lorries and cyclists going straight ahead die from their injuries. The number of killed cyclists varies significantly from year to year. But seen over a longer period, cyclists in right-turn accidents involving lorries constitute 15-20 % of all cyclists killed in traffic. Two-thirds of the

fatal right-turn accidents occur at signalized intersections.

The describe measures

Initially, some general recommendations regarding for example intersection design will be presented. These recommendations are relevant in both signalized and non-signalized intersections.

The primary focus is, however, on measures that can be used in signalized intersections on roads with a cycle track or cycle lane, since this is where most of the severe right-turn accidents happen.

In terms of the geometric design and the basic regulation type, there are generally three alternatives which are recommended in signalized intersections. These are:

- right turn lane and cycle track (possibly cycle lane)
- right turn lane and truncated cycle track (possibly cycle lane)
- separate phasing

In the design involving a right turn lane and cycle track, it is obvious to add

one or more of the following measures, which are also described in the leaflet:

- removal of reserve between carriageway and cycle track
- advanced stop lines for bicycles and possible bike box
- “pre-green” for cyclists

The last part of the leaflet also describes a fourth type of geometric design:

- offset passage

Earlier Danish experience with the offset passage design is too scarce to form a basis for an actual recommendation of the solution as a specific measure against right-turn accidents, just as no well-documented recommendations can be given concerning the detailed design. However, a new Danish behavioural study suggests that intersections with offset passage result in fewer conflicts between right-turning cars and cyclists going straight ahead than other intersection types, and it has therefore been decided to include the solution in this leaflet.

Measures related to vehicle design or warning devices (such as early warning systems with electronic detection of cyclists) or measures relating to traffic rules, behaviour and control are not described in this leaflet. Instead, reference is made to the descriptions in the above-mentioned "Strategy to prevent accidents between straight going bicycles and right turning lorries".

General recommendations

The solutions presented in this leaflet may help reduce the risk of right-turn accidents, but none of them can eliminate the risk entirely. The possibility of human error will always be present as long as lorries and cyclists travel on the same roads and may cross each other's route without grade separation.

Generally, it should therefore be ensured that points of conflict between car traffic and bicycle traffic are avoided or reduced in number. This should be done without resulting in significant detours and delays for cyclists, while ensuring safety at the same time. This ensures the greatest possible use of the bicycle facilities and reduces the risk of unintentional manoeuvres which surprise other road users.

For example, in connection with construction and major renovations of

existing intersections, it should be considered (depending on accident frequency) if it is practicable to establish grade-separated solutions where the bicycle traffic does not have to cross car traffic flows at the same level.

Provision of sight distance in intersections

In all at-grade intersections (with or without signal) where a right-turning car must cross a cycle track, right-turning drivers –including lorry drivers – must be able to see sufficiently far back on the right hand side. A sight distance length of 70 m behind to the right means that a driver in a right-turning lorry with a trailer can see far enough back to be able to cross the cycle track without requiring a cyclist or moped driver going straight ahead to stop.

In signalized intersections this is obviously important in cases where the signals are phased in such a way that both bicycles and right-turning cars fully or partially have a green light at the same time. However, also in intersections where the signal control in theory separates the parties completely, the necessary sight distance should be provided, since complex signal control will always entail a risk that a road user runs a red light.



Right-turn lanes and cycle track/cycle lane

For cyclists, a high level of safety, good traffic flow and comfort can be achieved when the cycle track (cycle lane) is led all the way up to the intersection and a separate right-turn lane has been established for the vehicle traffic at the same time. Without a separate right-turn lane for vehicle traffic, this solution cannot be recommended.

Removal of verge between carriageway and cycle track

On the last 30-50 m before the stop line, there should only be kerbed edges or a wide, raised edge line between the cycle track and the nearest lane (right-turn lane).

Right-turning lorries and vans thus have a better chance of seeing cyclists going straight ahead in their side mirrors on the right hand side. This will probably

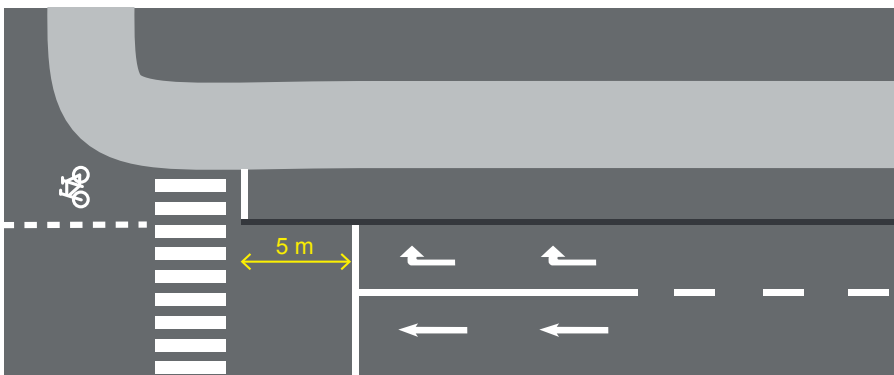
also enhance the turning drivers' recognition of their duty to give way to cyclists going straight ahead as well as both parties' attention to each other.

Advanced stop lines for bicycles and possible bike box

When there is a cycle track or lane right up to the intersection, an advanced stop line for bicycles will make cyclists visible in the natural field of vision of the right-turning drivers. This applies, however only to the situation where both parties after stopping for red light start to move simultaneously at a green light.

This is particularly important in relation to right-turning lorries. New lorries have mirrors which, in theory, make it possible for drivers to see both immediately in front of and along the sides of the car

Principal layout: Advanced stop line for bicycles and possible bike box



Bike box in Copenhagen



solely by means of the mirrors. However, experience from accident analyses shows that it can be difficult for drivers to check all the mirrors at the right time and that the mirrors are not always adjusted correctly. An advanced stop line for bicycles gives lorry drivers a direct view (without the use of mirrors) of cyclists who have stopped by the advanced stop line and await a green light for driving straight ahead.

A bike box is an additional area for bicycles in front of the vehicle stop line in the right-turn lane, where the area is clearly marked with for example blue paint with a white bicycle symbol.

The stop line for motor vehicles should always be retracted 5 m from the cyclists' stop line, which is normally placed before the pedestrian crossing. If the line is retracted less than 5 m, there will still be some lorry drivers who cannot see the waiting cyclists directly. If the stop line for drivers is retracted for all adjacent lanes in the approach, slower or late crossing pedestrians will also become more visible to the waiting drivers – especially if there are cars waiting by the stop line in all lanes of the approach. When establishing advanced stop lines for cyclists, safety times should be checked and intergreen time should possibly be adjusted.

Advanced stop lines for bicycles and "pre-green" for cyclists



An advanced stop line for bicycles can be combined with a bike box. Danish experience with this measure is relatively scarce, meaning that no official guidelines have been prepared for the detailed design and road marking. However, international experience indicates that the box may have an effect when it comes to right-turn accidents.

The Danish Road Directorate will be testing bike boxes in cooperation with Danish municipalities starting in 2015.

"Pre-green" signals for cyclists

If it is not possible to retract the stop line for cars by 5 m, it is possible to combine a slightly shorter retraction of the stop line by giving a pre-green

light for cyclists a few seconds before the cars. This gives drivers a chance to see the cyclists, who will also be able to pass through the intersection before the cars start to turn right.

This solution can be combined with giving cyclists a red light a few seconds before the cars so that the right-turning traffic have time to turn right without coming into conflict with the cyclists going straight ahead. In that connection, the Danish Road Directorate wishes to point out that a solution with a green arrow signal for right-turning cars followed by a regular green light (for both bicycles and cars) generally cannot be recommended.

Right turn lane and truncated cycle track/cycle lane

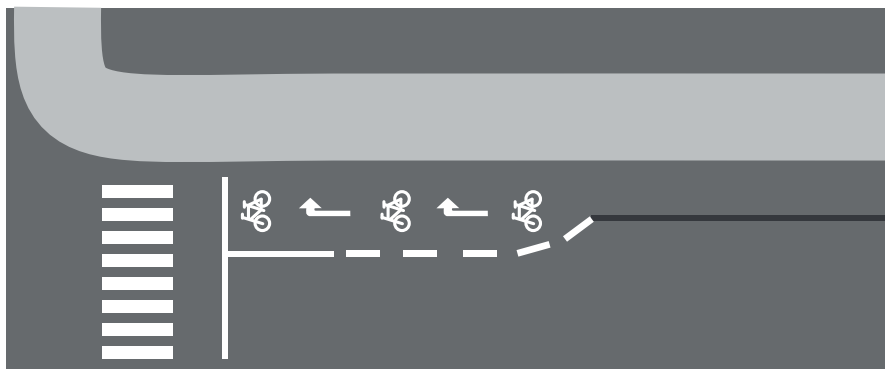
Another solution would be to interrupt the cycle track or lane 15-25 m before the stop line and let the cyclists continue in a right turn lane together with the right-turning cars. This reduces the accident risk since cyclists and right-turning motorists are given the chance of weaving before the intersection, and the cyclists going straight ahead can position themselves on the left-hand side of the right-turning cars.

The section up to the stop line is marked as a right-turn lane with bicycle symbols. The width of the lane must be wide enough to accommodate both cyclists, mopeds and right-turning traffic.

This solution should only be used when the right-turn lane for car traffic is a designated right-turn lane that is not also used by traffic going straight ahead.

This solution works well in safety terms – especially on sections with downhill grade towards the intersection – but it is done partly at the expense of the cyclists' perceived safety and mobility since they will need to weave with the motor vehicle traffic towards the intersection. If the bicycle traffic volume is large, it may also be difficult for right-turning drivers to weave into the flow of cyclists.

Principal layout truncated cycle track



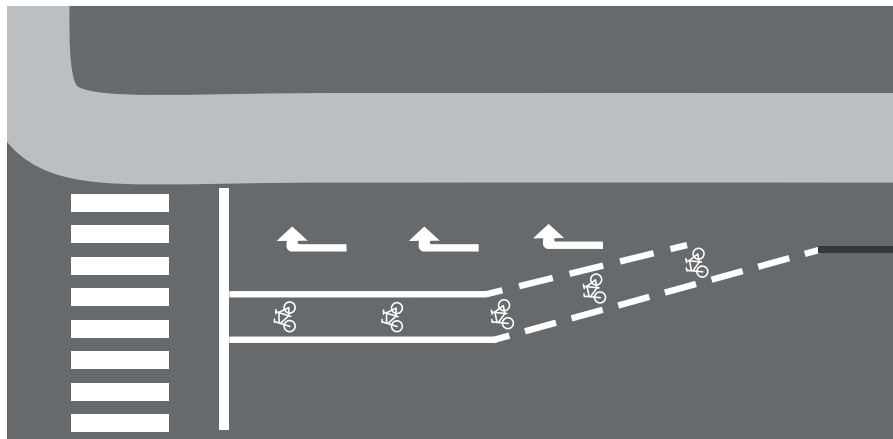


The truncated cycle track can be combined with a cycle lane for the cyclist going straight ahead and turning left which is placed between the lane for cars going straight ahead and the right-turn lane. This cycle lane must be at least 1.50 m wide including edge

This solution is only applicable on roads with speeds of 50 km/h or less. The solution works well in safety terms, but many cyclists feel unsafe about having to drive between the car traffic going straight ahead and the right-turning car traffic.



Principal layout: truncated cycle lane and lane for cyclists going straight ahead



Separate phasing

A signal solution in which the conflict between right-turning drivers and cyclists going straight ahead is controlled separately can also be recommended.

Separate phasing is a technical solution where each traffic flow is regulated by its own separate signals.

Generally, the bicycle traffic going straight ahead is allowed to go first, while the right-turning car traffic has a

red light. Then the cyclists will have a red light, and the right-turning car traffic will be given a green light.

In terms of geometry, this solution does not have to differ substantially from the solution with a right-turn lane and a cycle track. However, several variants of the solution exist – from only providing separate signal control for one or more right-turning conflicts to a fully separate signal control system of all traffic flows

Separate phasing of traffic lights





in the intersection (i.e. a conflict-free intersection). Besides road marking of separate lanes for all the separately controlled traffic flows, such solutions will often require additional refuges for placing of signals.

In general, intersections with separate phasing/conflict-free signal control work well in road safety terms. The Danish Road Directorate has no documentation to the effect that significant

safety differences should exist between the different solutions. However, separate signal control takes up some of the capacity, and in intersections with heavy traffic, this solution may result in long waiting times for both drivers and cyclists. Moreover, separate phasing (depending on how many flows that are controlled separately in the intersection) requires quite a lot of space, meaning that this solution cannot be established in all intersections.

Offset passage

In this solution, cycle lanes have been led around the corners of the intersection, and cyclists' crossing of the intersecting road is slightly offset towards the right in relation to the original direction of travel.

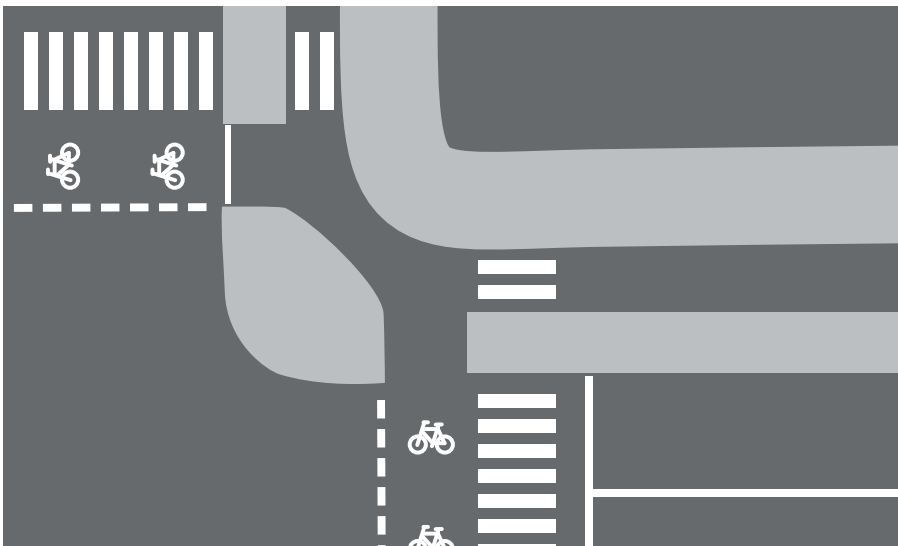
The design makes it possible to exempt cyclists from the signal control when driving into the intersection. The right-turning cyclists can thus bypass the signal control, and the cyclists going straight ahead will not be controlled by a signal until the stop lines right by the intersecting road.

Cyclists waiting at the stop line are thus placed a few metres in front of the

drivers' stop line and a few metres offset to the right. This design also means that left-turning cyclists will be directed behind a stop line after they have passed the intersecting road and therefore have to wait for a green light in the new direction of travel.

When conflicts between vulnerable road users need to be handled independently of the signal control, it requires refuges for pedestrians and waiting areas for cyclists between the carriageway and the cycle track. This solution thus takes up more space than the more conventional designs and will not always be possible in existing intersections surrounded by dense housing.

Principal layout: offset passage





Further information

Strategy to prevent accidents between straight going bicycles and right turning lorries:
<http://www.trm.dk/en/publications/2014/strategy-to-prevent-accidents-between-straight-going-bicycles-and-right-turning-lorries>

Collection of Cycle Concepts, 2012:
http://www.vejdirektoratet.dk/DA/viden_og_data/publikationer/sider/publikation.aspx?pubid=000061713

The Danish Road Directorate's headquarter is situated in Copenhagen and local offices are situated in Aalborg, Skanderborg, Middelfart, Næstved and Fløng.

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