Cyclist Safety at Signalised Junctions

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Summary:

The Danish Road Directorate has in co-operation with 5 Danish municipalities applied new layouts at signalised junctions. The objective was to improve cyclist safety. Before-and-after behavioural studies showed that the layouts probably improved the cyclist safety.

The new layouts consist of truncated cycle tracks with narrow cycle lanes to the stop lines, "slalom" cycle tracks/lanes, staggered stop lines, marking of cycle crossings and profiled stripes.

Before-and-after accident studies show that the number of bicycle accidents dropped at 7 out of 11 signalised junctions. A 30% drop in accidents between right-turning cars and straight-on riding cyclists occurred. On road sections with entry/exit for motorists, where the cycle track was truncated, the number of bicycle accidents increased significantly.

The paper and presentation include an overview of studies about cyclist safety at signalised junctions. Based on these studies and practical experiences a presentation of best practice to design and operate signalised junctions with focus on cyclist safety is given.

1. Introduction

Today, 70-75% of the bicycle accidents at signalised junctions in Denmark occur, where cyclists are separated from motorised traffic before the junctions by e.g. kerbs, marking and dividing verges. This share of bicycle accidents at signalised junctions is still increasing due to more and more separation. 38% of the Danish municipalities built cycle tracks and paths in 1997 (1). The challenge in terms of cyclist safety at signalised junctions is to develop safe junction designs on roads, where cyclists are separated from motorised traffic on links.

2. New layouts at signalised junctions

In 1991-93 new layouts were applied at 11 signalised junctions. Results from before-and-after studies of motorists and cyclists behaviour show, that the new layouts probably have positive safety effects (2).

The behavioural studies were followed up in 1999 by a before-and-after accident study (3). This paper describes the results from the accident study.

2.1 Description of layouts

The new layouts at signalised junctions consist of truncated cycle tracks with narrow cycle lanes to the stop lines, "slalom" cycle tracks/lanes, staggered stop lines, marking of cycle crossings and profiled stripes. Figure 1 and 2 show two out of four different layouts.

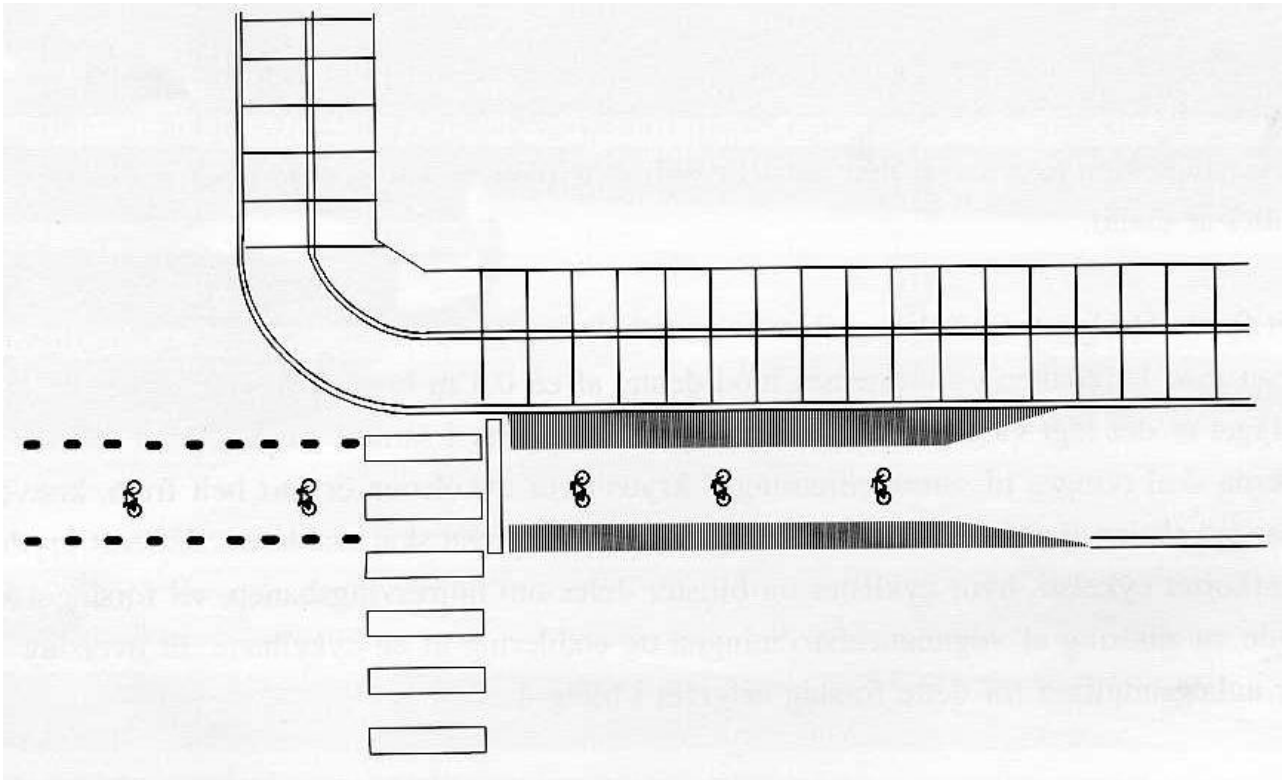

Figure 1. Draft of layout with truncated cycle track, narrow cycle lane and marked cycle crossing.

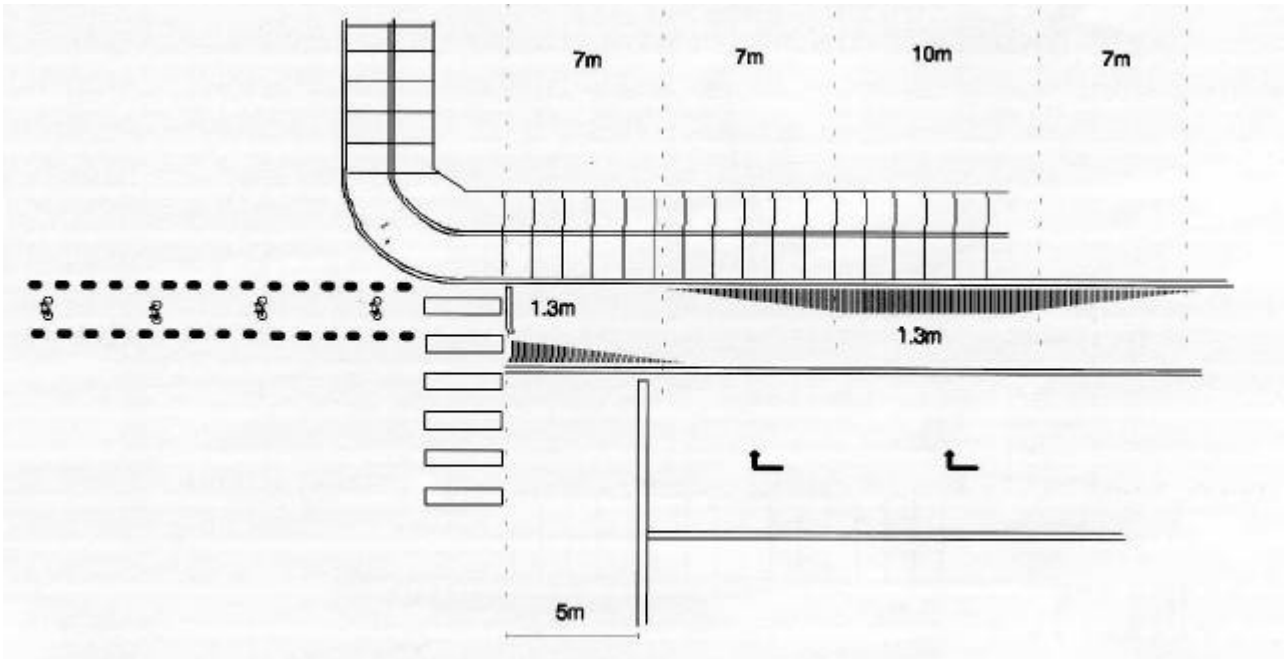

Figure 2. Draft of layout with "Slalom" cycle track to stop line, staggered stop lines and marked cycle crossing.

2.2 Method

The accident study is based on police records. Before and after periods are not necessarily of the same length, but a period is maximum 5 years. Control groups based on accidents at signalised

junctions in the same municipalities, where the new layouts were applied, were set up to take the general accident development into account - month by month. Regression-to-the-mean effects are not part of the study, since accidents were not part of the selection of junctions.

The safety effect is measured as the difference between expected and observed accidents in the after period. The number of expected accidents is calculated by multiplying the number of accidents in the before period by a factor based on the relevant control group.

2.3 Results

Moped riders must drive on cycle tracks in Denmark. Therefore is bicycle and moped accidents mixed in the groups of accidents in table 1.

Junction no.	Group 1		Group 2		Group 3		Group 4	
	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.
1	0.0	0	0.0	2	7.2	11	3.7	7
2	0.0	0	4.1	2	4.1	4	12.8	12
3	0.0	0	1.4	0	1.4	1	2.1	7
4	1.0	2	6.8	6	1.0	1	2.9	7
5	0.0	1	14.8	20	8.2	8	20.1	24
6	0.0	1	3.9	3	12.6	13	36.5	33
7	0.0	0	2.0	0	10.2	5	12.8	15
8	-	-	1.6	3	3.1	3	6.8	4
9	-	-	0.0	0	0	1	2.6	8
10	0.0	0	4.7	4	0	2	2.6	3
11	0.0	0	0.8	0	3.1	0	8.5	10
Total	**1.0**	**4**	**40.0**	**40**	**50.8**	**49**	**111.4**	**130**

Explanation of accident groups 1-4:

Group 1: Accidents involving at least 1 cyclist or moped rider on the road section before the stop line, where new layouts have been applied.

Group 2: Accidents involving at least 1 cyclist or moped rider comming from an entry, where new layouts have been applied. (In the junction after the stop line)

Group 3: Accidents involving at least 1 cyclist or moped rider comming from other Entries.

Group 4: Accidents without cyclists and moped riders involved.

Table 1. Number of expected and observed accidents after the application of new layouts in 11 signalised junctions.

The number of accidents in group 2 dropped at 7 signalised junctions. Accident group 2 is the accidents, which most obviously would change in numbers due to the redesign of the junctions. At 3 junctions there was an increase in accidents (group 2). Only 6 of the 87 accidents in group 2 involved moped riders.

The total number of accidents (group 2) is unchanged, which primarily is due to an increase of accidents at junction 5, where almost half of the accidents occurred. The accidents in group 2 at junction 5 was at the same level as expected in 4 out of 5 years, but in 1 year there occurred 6 accidents with left-turning motor vehicles and straight-on riding cyclists more than expected. This

unexpected increase can not be explained by changes in signal control or road works. If junction 5 is left out, the total number of accidents (group 2) decreased by 20%.

A 30% drop occurred in accident group 2 between right-turning cars and straight-on riding cyclists occurred at the 11 junctions.

On road sections with entry/exit for motorists (at junction 4, 5 and 6), where the cycle track was truncated, the number of accidents (group 1) increased. It is therefore advised not to truncate the cycle track on a road section with entry/exit for motorists. 4 of 5 accidents in group 1 involved moped riders.

It is fair to say that the new layouts did not change the number of bicycle accidents considerably.

3. Best practice

At signalised junctions, the drivers' and cyclists' expectation of conflicts between one another and the visibility of cyclists is crucial for cyclist safety. If the driver is aware of the possibility of a conflict with a cyclist and expects this to occur, then the driver is more prone to reduce speed and look out for cyclists. For example is the individual cyclist safer at a signalised junction with many cyclists than at a junction with few cyclists.

The visibility of cyclists might be obstructed by other vehicles, signs, trees, noise barriers etc. Recognition of the junction and visibility of signals are also important.

Safety measures relevant for cyclists at signalised junctions are most often implemented in order to improve visibility and to increase expectation. Some studies about and Danish experience with safety measures and cyclist safety at signalised junctions are mentioned in the following.

3.1 Staggered stop lines

At all signalised junctions it is recommended to recess the stop lines for motor vehicles in all lanes by approximately 5 metres relative to the pedestrian crossing or the cyclists' stop line. By doing so, pedestrians and cyclists are more visible in connection with a change of signal, and cyclists enter the junction earlier so that many conflicts are avoided.

A Danish accident study showed a 35% reduction in the number of accidents between right-turning motor vehicles and straight-on riding cyclists, or in other words, 9 out of 10 bicycle accidents at the start of green were prevented (2). A Danish behavioural study showed that the same share of motorists stop before a recessed stop line as before a stop line next to the pedestrian crossing (4).

Another possibility is advanced stop lines, where cyclists stop in front of turning motor vehicles. This measure has the same benefits as staggered stop lines and maybe increases the capacity of the junction.

3.2 Cycle crossings

Marking cycle crossings can increase motorist expectation of a coming cyclist at many signalised junctions. 4 different markings of cycle crossings are used in Denmark. 3 consist of white stripes

and cycle symbols and 1 is blue also with white stripes and cycle symbols. It is very important that drivers understand and notice the meaning of the markings.

A Danish study showed a 38% reduction in the number of bicycle accidents due to marking of blue cycle crossings. Furthermore, the study showed that especially accidents between motor vehicles turning left and straight-on riding cyclists were prevented. Motorists seem to have transferred some of their awareness from pedestrians to cyclists, as there was an increase in pedestrian accidents (5).

3.3 Signals

Cyclist signals can be used to give cyclists green 2-4 seconds before motorists. Pre-green has almost the same safety benefits as staggered stop lines. Pre-green is often used in connection with bus priority.

Cyclist signals are also used to reduce green time for cyclists to facilitate the flow of right-turning motor vehicles. Green arrow for right-turning motorists means early cut-of for cyclists. There should be 2 seconds of red cyclist signal before the green arrow is switched on.

At junctions with two or more turning lanes from one entry, these turning lanes should have their own signal stage, because it is often difficult for motorists in at least one of the turning lanes to see the cyclists. Green time is thus reduced for cyclists riding straight-on or turning left. A green arrow or a separate stage for left-turning motorists is often beneficial for cyclist safety at junctions, where the left-turning motorists crosses two or more straight-on lanes for motor vehicles.

3.4 Cycle tracks/lanes to the stop line

At signalised junctions with a right-turn lane for motorists and where cyclist speeds are low or normal, it can be a good idea to continue the cycle track/lane to the stop line. By doing so, the cyclists feel safer and it makes it possible to apply staggered stop lines, cycle crossings, cyclist signals and so on. Typical average speeds among free-riding cyclists at signalised junction on flat roads are 20-25 km/h.

At junctions with many right-turning trucks a cycle track/lane to the stop line should be used with caution as truck drivers have difficulty in detecting cyclists on the right side of the truck. A part of the safety problem with right-turning trucks can be solved by staggered stop lines.

It is very important that motorists and cyclists are well aware of one another. This mean that all visibility obstructions should be removed up to at least 20 metres before the stop lines. A Swedish study showed that cyclists riding on a cycle track with a dividing verge to the carriageway have a higher risk than without a dividing verge (6). Parked cars, bus stops, road bends, signs and posters etc. may also lower the visibility of cyclists.

The right-turn lane for motorists is important at signalised junctions because motorists otherwise will use less time on right-turns. It order to make space for a right-turn lane and create better interaction between motorists turning right and cyclists continuing straight-on, a narrow cycle lane can replace a wide cycle track/lane the last 20-60 metres before the stop line. This measure, however, reduces capacity for bicycle traffic if not combined with an advanced stop line.

3.5 Truncated cycle tracks/lanes

At signalised junctions with cyclists travelling at high speeds it is important to truncate the cycle track/lane for safety reasons. In the mirrors of the car the cyclist becomes less and less detectable the longer back of the car he rides. When cyclists are riding fast, e.g. 40 km/h down hill, left-turning motorists have to be able to see the cyclists about 35-50 metres before their stop line. Almost the same sight distance is needed for right-turning motorists if the cycle track/lane ends at the stop line. If the cycle track, however, is truncated the right-turning motorists do not need the very long sight distance to cyclists, because cyclists and motorists have to merge with one another.

If truncation of a cycle track/lane is the only possibility of creating space for a right-turn lane, it is presumably also better from a road safety point of view to truncate the cycle track/lane.

At junctions with a truncated cycle track there should be no entries and exits on the 'truncated' section before the junction. Truncated cycle tracks/lanes should not be used at junctions with many child cyclists as this solution creates a sense of perceived risk - and children cycle slowly.

Generally, the differences in cyclist safety of truncated cycle tracks, cycle tracks to the stop line and the measures described in section 2 are not big, if sight obstructions are removed and the cyclists ride at normal or low speeds. Other aspects like perceived risk and capacity must then be decisive for the choice of measure.

3.6 Cycle lane between right-turn and straight-on motor vehicle lanes

At large signalised junctions a cycle lane can be marked between the right-turn motor vehicle lane and the straight-on motor vehicle lanes. The underlying idea is to eliminate the conflict between motor vehicles turning right and straight-on riding cyclists by having the less dangerous merge manoeuvres before the junction. At the same time straight-on riding cyclists are more visible for oncoming motorists turning left. This measure can be combined with a cycle crossing in the junction area. A Danish accident study of this measure has not been able to document any safety impact (7).

4. Conclusion

Cyclist safety at signalised junctions can be improved by marking, changes in layout, signal control and removal of visibility obstructions. Marking and other low-cost measures probably have the highest cost-effectiveness, and it seems like that these low-cost measures often are quite effective. In Denmark, marking and minor changes in signal control often have a first year benefit of more than 100%. Even minor changes in layout like truncation of a cycle track can be very cost-effective.

Larger changes like implementing conflict-free signal control (can easily cost 1 million euro or more in built-up areas) or reducing the number of lanes in order e.g. to improve visibility and reduce capacity, are most often not very cost-effective, but might be the only way to prevent some accidents.

A before-and-after accident study showed that the number of bicycle accidents dropped at 7 out of 11 signalised junctions, where new layouts were applied. The new layouts consist of truncated cycle tracks with narrow cycle lanes to the stop lines, "slalom" cycle tracks/lanes, staggered stop

lines, marking of cycle crossings and profiled stripes. A 30% drop in accidents between right-turning cars and straight-on riding cyclists occurred. On road sections with entry/exit for motorists, where the cycle track was truncated, the number of bicycle accidents increased.

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