

Road safety and perceived risk of cycle facilities in Copenhagen

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This before-and-after study covers the construction of one-way cycle tracks and lanes, blue cycle crossings and raised exits. It is the biggest study of its kind so far carried out in Denmark. The effects on road safety of all types of traffic both at junctions and on road sections for both accidents and injuries are examined. The effects on the volumes of motor vehicles as well as on bicycle and moped traffic are examined with regard to the construction of one way cycle tracks and lanes. Lastly, cycle facilities impact on cyclists' perceived risk and satisfaction on road sections and at junctions is also examined.

Introduction

At the request of the Municipality of Copenhagen, Trafitec carried out a comprehensive study to examine the effects cycle facilities in Copenhagen were having on road safety, traffic volumes and perceived risk.



Figure 1. Photos of cycle track (top left), cycle lane (bottom left), blue cycle crossing (top right) and raised exit (bottom right).

By investigating accidents and traffic counts both before and after the construction of various facilities, the effects upon road safety and traffic volumes were discovered, while perceived risk was checked by interviewing cyclists on road sections and at junctions of different designs. The amount of data is enormous with more than 8,500 accidents, 1,500 traffic counts and 1,000 interviews investigated and many results are therefore statistically significant.

The studies are to be found in three Danish reports: "The effects of cycle tracks and lanes", "The effects of raised exits and blue cycle crossings" and "Cyclists' perceived risk and satisfaction". These reports can be accessed on www.vejpark.kk.dk and www.trafitec.dk. The methodology is described in detail in the reports.

Road safety of cycle tracks

The construction of cycle tracks has resulted in a slight drop in the total number of accidents and injuries on the road sections between junctions of 10% and 4% respectively. At junctions on the other hand, the number of accidents and injuries has risen significantly, by 18%. A decline in road safety at junctions has undoubtedly taken place after the construction of cycle tracks. If the figures for the road sections are combined with those for the junctions, an increase of 9-10% in accidents and injuries has taken place.

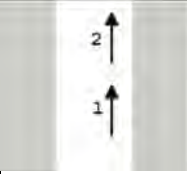
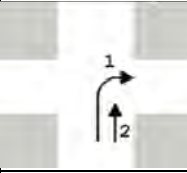
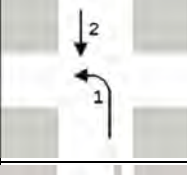
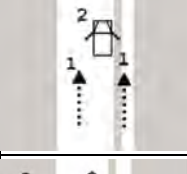
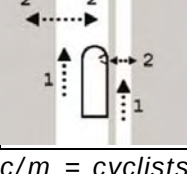
The safety effects of various construction projects are statistically different in some cases. The safety effects mentioned above cannot therefore be generalised. The reason for this is that the accident composition and the road design are different on those individual streets where cycle tracks have been constructed. Some road designs with cycle tracks are safer than others.

The increase in injuries due to the construction of cycle tracks arises because there are more injuries to pedestrians, cyclists and moped riders at junctions. There has been an increase of 28%, 22% and 37% respectively for these three road user groups.

The increase in injuries to women was 18%, whereas there was only a small rise in injuries to men, just 1%. The increase in injuries is especially large among females under 20 years of age on foot and bicycle, as well as female pedestrians over the age of 64. On the other hand, there was a considerable fall in injuries among older cyclists and children in cars of both sex.

The accident composition has changed markedly after the construction of cycle tracks. Many changes have taken place in various accident situations, with both rises and falls of hundreds of accidents. In table 1, only statistical significant changes are shown, where effects with + denote an increase, while effects with – denote a decline.

From table 1, it can be deduced that the construction of cycle tracks has resulted in three important gains in road safety: fewer accidents in which cars hit or ran over cyclists from the rear, fewer accidents with cyclists turning left and fewer accidents in which cyclists rode into a parked car. These gains were more than outweighed by new safety problems: more accidents in which cyclists rode into other cyclists often when overtaking, more accidents with cars turning right, more accidents in which cars turning left drove into cyclists as well as more accidents between cyclists and pedestrians and exiting or entering bus passengers.

Typical accident situation	Specific type of accident and manoeuvre	Results	
		Accidents	Injuries
	car against c/m in the same direction	-63 %	-68 %
	c/m against c/m in the same direction	+120 %	+201 %
	car against right-turning car	+70 %	+177 %
	right-turning car against c/m	+129 %	+161 %
	right-turning car against pedestrian	+77 %	+84 %
	left-turning car against c/m	+48 %	+61 %
	left-turning c/m	-41 %	-45 %
	c/m against parked car	-38 %	-56 %
	entering and exiting bus passengers	+1951 %	+1762 %
	c/m against pedestrians	+88 %	+63 %

c/m = cyclists/moped riders. NB the category of mopeds in Denmark confined to driving on cycle tracks is limited to a top speed of 30 kph.

Table 1. Significant safety effects in accidents and injuries categorised by accident situation. About 90% of those involved in accidents in category c/m are cyclists. The figures for c/m could therefore be read as for cyclists.

Parking and cycle tracks

Prohibited parking is one of the most serious reasons why the construction of cycle tracks brings about more accidents and injuries. Prohibited parking on a road with a cycle track results in cars being parked on side streets, with a consequent increase in turning traffic, especially at right of way regulated junctions and more accidents resulting from turning cars. The construction of cycle tracks and prohibition of parking resulted in an increase in accidents and injuries at junctions of 42% and 52% respectively. The construction of cycle tracks combined with permission to park also resulted in an increase in accidents and injuries but of only 13% and 15% respectively. At right of way regulated junctions with continuous cycle track forming a raised exit, the number of accidents on no parking roads increased by 56%, but by only 23% on roads with parking permitted. There is no difference in the safety statistics at signalised junctions between roads with parking permitted or prohibited respectively.

It is quite logical that parking conditions have such great significance for accidents at right of way regulated junctions. In the study, the road sections with no parking between junctions are about 80 – 90 metres long with room for a total of about 15

– 20 cars parked on both sides of the road. Due to the constant changing of the parked cars, a parking prohibition on a main road causes 100 – 200 cars to park in one side street per day, where previously about 200 – 500 cars drove per day. Turning car traffic at junctions with minor side roads often increases by 25 – 50% when such a parking prohibition is in operation.

On road sections with no parking, there was a 24% increase in accidents, whereas on sections with parking permitted the accident rate fell by 14%. Parking conditions are not thought to affect the number of injuries on sections between junctions, since these fell by 9% and 8% respectively with regard to no parking or parking permitted. When parking is permitted, there are fewer parking accidents, rear-end collisions and pedestrian accidents. Illegally parked cars often cause more accidents than legally parked cars. The total width of drive lanes is reduced when parking is permitted, resulting in increased safety for pedestrians when they cross.



Figure 2. Photos of a shortened cycle track extended into a narrow cycle lane (left), an advanced cycle track with a blue cycle crossing and a pre-green light for cyclists (middle), a shortened cycle track extended into a right turn-lane (right).

Shortened or advanced cycle tracks

At signalised junctions, it has been found that the number of accidents with traffic from entry lanes with a shortened cycle track (see figure 1 right) fell by 30%, whereas the number of injuries increased by 19%. A significant improvement in car drivers' safety occurred when a shortened cycle track was constructed, whereas cyclists' and especially pedestrians' safety deteriorated.

The accident rate for entry lanes with an advanced cycle track increased significantly by 25%, whereas injuries increased by only 9%. The increase is due to more property damage only accidents involving cars and right-turn-accidents. The accident rate for entry lanes with an advanced cycle track without turn lanes for cars increased by 68% for accidents and 67% for injuries. The figures for entry lanes with turn lanes and advanced cycle track showed a 15% increase in accidents and a fall of 5% in injuries.

A comparison shows that entry lanes with an advanced cycle track without turn lanes for cars is the design that functions worst. Shortened cycle tracks and advanced cycle tracks with turn lanes for cars are equally effective as far as safety goes. There is a difference, however, advanced cycle tracks are best for pedestrians and cyclists, whereas shortened cycle tracks are best for car occupants.

Road safety of cycle lanes

The construction of cycle lanes has resulted in an increase in accidents of 5% and 15% more injuries. These increases are not statistically significant. The decline in road safety can be seen both at junctions and on sections. The increases occurred especially amongst cyclists and moped riders where increases in injuries is tendential amounting to 49%.

In line with cycle track statistics, there was a larger increase in injuries among women with the construction of cycle lanes, 22%, whereas the figure for men was only 7%. There was a fall in injuries among children under 20 and an increase among those aged 20 – 34.

The construction of cycle lanes has a markedly different effect on the accident composition compared to the construction of cycle tracks. The construction of cycle lanes did not apparently lead to an appreciable fall in accidents between cars driving straight ahead and cycles/mopeds going in the same direction, or accidents between left-turning cycles/mopeds and other traffic. Conversely, the construction of cycle lanes did not apparently lead to an increase in accidents between cycles/mopeds and pedestrians or accidents between left-turning cars and cycles/mopeds.

There are however similarities. The number of accidents involving cars turning right increased by 73% with the construction of cycle lanes. There was also an considerable increase in accidents between cyclists going straight ahead and other cyclists going in the same direction.

Road safety of blue cycle crossings

There was a 13% decrease in accidents at signalised junctions where only one blue cycle crossing had been marked. At signalised junctions where two or four blue cycle crossings had been marked, however, increases of 23% and 61% respectively occurred. Corresponding changes in the number of injuries for one, two and four blue cycle crossings are a fall of 22%, and increases of 37% and 138% respectively. A special version of two blue cycle crossings is one crossing at right angles to another in a T-junction. In this version, there was a fall in accidents and injuries of 37% and 69% respectively.

There is a clear relationship between the number of marked blue cycle crossings and the number of cycle/moped and car accidents. The more blue cycle crossings, the greater the risk of these two types of accidents. The more arms a junction has, the less the safety effect of the blue cycle crossings, irrespective of the number of blue crossings marked and the junction's size. The size of the junction and the amount of incoming car traffic does have a significance. The smaller the junction is, the safer it becomes, when one blue cycle crossing is marked or two blue cycle crossings at right angles to each other.

At junctions with one blue cycle crossing, the marking of the crossing has been especially advantageous in terms of safety for the flow of cyclists/moped riders who could use the cycle crossing in the after period, as well as for pedestrians on the pedestrian crossing immediately next to the blue cycle crossing. For these groups, the number of accidents and injuries fell by 37% and 44% respectively. A fall of 52% also occurred in accidents involving right-turning cars among these

'changeable accidents'. Other accidents than 'changeable accidents' only changed slightly with a 5% decrease.

The signalling value provided to road users by one blue cycle crossing results in a safety benefit. The smaller the junction is, the greater the influence on the accident figures this signalling value acquires and the more road users focus upon those problems of which the blue cycle crossing is trying to warn them. The same is true when there are two blue cycle crossings at right angles to each other.

At junctions with two parallel or four blue cycle crossing the signalling value is judged to be lost. Here, cyclists and car drivers drive over on red more often after blue cycle crossings have been marked and there are more frequent examples of rear-end collisions.

Safety of raised exits

The construction of raised exits at non-signalised junctions has brought about a slight decline of 5% in the number of accidents. The effect of 5% is not statistically significant. However, the number of accidents between pedestrians and motor vehicles has fallen significantly by 54%, after the construction of raised exits. Accidents involving cyclists and moped riders has fallen slightly by 12%, while accidents involving only motor vehicles has increased slightly by 11%.

At T-junctions, the number of accidents increased slightly by 10%, while accidents at 4-armed junctions fell slightly by 18%. The safety effects was better at 4-armed junctions compared to T-junctions in all accident categories: pedestrian, cycle/moped and car.

Nothing indicates that the type of raised exit has any significance as far as safety goes. A footway raised exit, where the footway on the main road is slightly elevated over the junction with the side road, has just as high safety effect as a cycle track raised exit, where both cycle track and footway are elevated over the junction with the side road.

The construction of raised exits has an influence in three accident situations. Accidents between left-turning cars and other cars increase tendentially by 70%, while accidents between left-turning cars and pedestrians/cycles/mopeds and accidents between pedestrians and non-turning vehicles falls significantly by 49% and 51% respectively.

In the study of construction of cycle tracks, raised exits can indirectly be evaluated by comparing the effects of constructing continuous (with a raised exit) and interrupted (without a raised exit) cycle tracks at non-signalised junctions. The construction of continuous tracks resulted in an increase in accidents and injuries of 30% and 81% respectively at T-junctions. The figures for interrupted cycle tracks showed increases of 34% and 343% respectively. At 4-armed junctions, the number of accidents remained unchanged with the construction of continuous cycle tracks, whereas the number of accidents increased by 92% with interrupted cycle tracks. If parking bans and width of side roads are taken into consideration, it could be said that continuous cycle tracks (with the construction of raised exit) is safer than interrupted cycle tracks at both 3- and 4-armed non-signalised junctions.

Effects on traffic volumes

The construction of cycle tracks has resulted in an 18-20% increase in cycle/moped traffic and a decrease of 9-10% in car traffic on those roads where cycle tracks have been constructed. A considerable amount of these effects were already visible during the construction period, although the effects increased after roadworks were finished.

The construction of cycle lanes resulted in a 5-7% increase of cycle/moped traffic and an unchanged amount of car traffic on those roads where cycle lanes were marked. The effects of cycle lanes are not statistically significant.

Cycles comprise over 95% of cycle/moped traffic. The effects are valid for cycle traffic but it is not known whether they are valid for moped traffic on its own.

Cyclists' perceived risk

Cyclists feel most secure on roads with cycle tracks and most at risk on roads with mixed traffic. This is true for all cyclists, irrespective of their gender, age, purpose in cycling or familiarity with their route. Figure 3 shows that conditions in mixed traffic create considerably more feelings of risk than conditions on cycle tracks or cycle lanes. Cycle lanes are a middle path so to speak: somewhat less secure than cycle tracks, but considerably more secure and satisfactory than mixed traffic. Increased car traffic leads incidentally to cyclists feeling more at risk. Results regarding cyclists' security and satisfaction generally show considerable correlation.

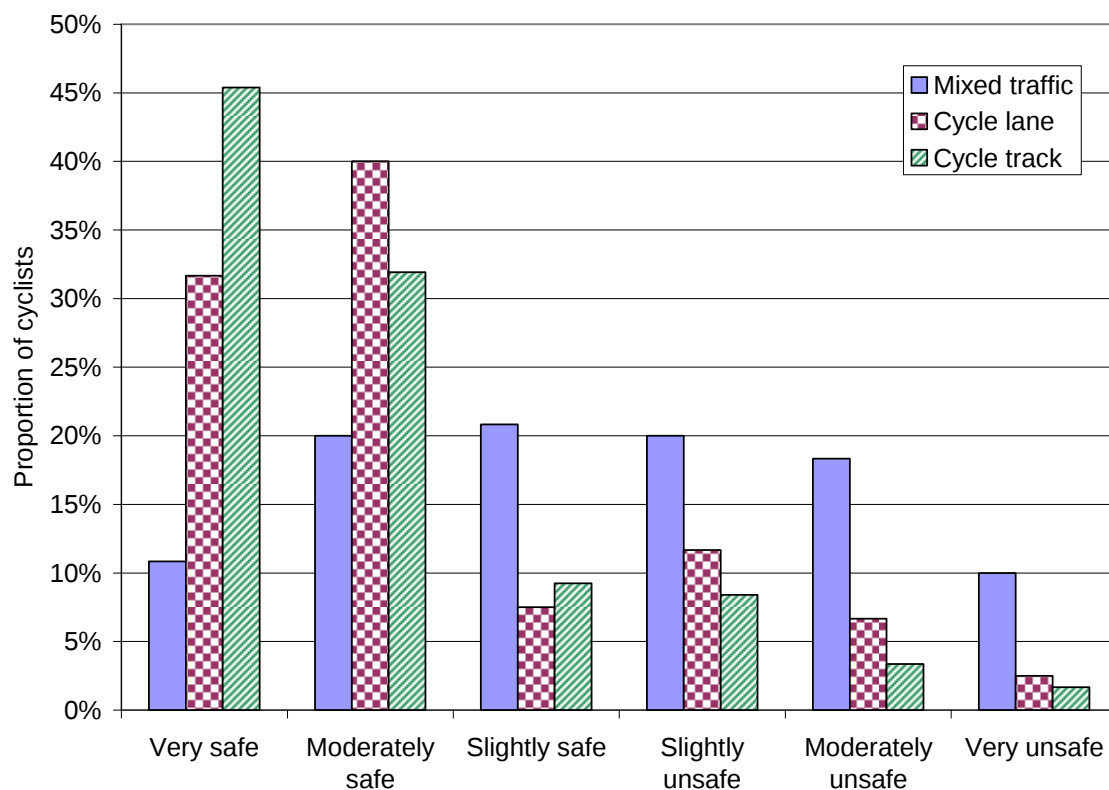


Figure 3. Division of answers to questions put to cyclists about their feelings of safety on roads with mixed traffic, cycle lanes and cycle tracks.

Cyclists feel safest at signalised junctions with a blue cycle crossing, whereas, somewhat strangely, cycle facilities immediately before the junction do not seem to have a significance. This can possibly be attributed to the fact that 10 metres after the junction cyclists have forgotten the conditions immediately before the junction. Nothing indicates that any of the three lay-outs - cycle track, shortened cycle track or narrowed cycle lane – influences the cyclists' feeling of security. It seems as if conditions within the junction itself create differences in the cyclists' perceptions. A blue cycle crossing makes cyclists more secure and satisfied, while increased car traffic and junction size make cyclists more insecure and dissatisfied.

62% of cyclists in the current study on cyclists' perceived risk answered that in general they feel secure in the traffic of Copenhagen. This is close to the result of the Bicycle Accounts of the Municipality of Copenhagen of 2004, where 58% of cyclists said that they felt safe when cycling in Copenhagen. This figure can be compared to the fact that 87% feel secure on roads with cycle tracks and 86% feel secure at signalised junctions with advanced cycle tracks and blue cycle crossings.

Conclusion

The construction of cycle tracks in Copenhagen has resulted in an increase in cycle traffic of 18-20% and a decline in car traffic of 9-10%. The cycle tracks constructed have resulted in increases in accidents and injuries of 9-10% on the reconstructed roads. It is possible to reduce the worsening in road safety; maybe safety can be improved in the future because safety effects are clearly dependent on a number of design factors and regulatory conditions. A safe construction of cycle tracks:

- o avoids greatly reducing possibilities for car parking
- o avoids entry lanes without turn lanes at signalised junctions
- o creates one and only one blue cycle crossing at signalised junctions
- o continue cycle tracks into raised exits at non-signalised junctions

It should be noticed that blue cycle crossings, retracted stop lines for cars and pre-green lights for cyclists have been used in only very few places on those streets where cycle tracks have been constructed in Copenhagen in the studied after periods. More extended use of these safety measures would very probably have improved road safety.

The construction of cycle lanes has led to an increase in cycle traffic of 5-7% with no change in car traffic. These cycle lanes have resulted in increases in accidents and injuries of 5% and 15% respectively on the reconstructed roads. The worsening in road safety occurs almost exclusively as a result of considerable increase in accidents and injuries among cyclists. More detailed traffic and design conditions were not studied in relation to cycle lanes, because the number of road sections and junctions was too restricted to offer any relevant statistical conclusions.

Cyclists feel most secure on cycle tracks and least secure in mixed traffic. Cycle lanes are a middle way. At junctions, the conditions within the junction itself seem to be most significant for cyclists' feelings of security. A blue cycle crossing increases cyclists' security, whereas more car traffic and a larger junction area increases insecurity.

Taken in combination, the cycle tracks and lanes which have been constructed have had positive results as far as traffic volumes and feelings of security go. They have however, had negative effects on road safety. The radical effects on traffic volumes

resulting from the construction of cycle tracks will undoubtedly result in gains in health from increased physical activity. These gains are much, much greater than the losses in health resulting from a slight decline in road safety.