# An experiment on the lateral steering behaviour of cyclists on narrow bidirectional cycle tracks

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## 1 INTRODUCTION

Cycling contributes to public health because it requires physical effort [1] and offers economic and environmental advantages over motorized transport [2]. However, 41,000 cyclists die every year in traffic crashes, 3% of the total worldwide [3]. Most fatal bicycle crashes are collisions with motor vehicles. Severe injuries among cyclists, however, are mostly due to single bicycle crashes and their numbers are increasing [4, 5]. An international review showed that the share of hospitalised casualties due to single-bicycle crashes varied from 3% to 41% of the total number of hospitalised casualties [6].

Cycle tracks encourage cycling and sufficient pavement width is important to prevent single-bicycle crashes and collisions between cyclists [7-10]. Requirements on the minimum width of a bidirectional cycle track in guidelines are generally based on a 75 cm standard cyclist width including cyclists' lateral deviation from a straight line of some 20 cm combined with buffer zones [11, 12] as depicted in Figure 1. Requirements include a buffer zone between cyclists for passing and overtaking and a buffer zone between the cyclist and verge (buffer 1 and 2 in Figure 1). For instance for bidirectional cycle tracks where mopeds are not allowed and with well-designed verges such as in in Figure 1, the current Dutch Design manual for bicycle traffic [13, 14] recommends a minimum width of 1.5 m: three 25 cm buffer zones plus two times half of the width of a 75 cm wide standard cyclist. The assumed buffer zones in guidelines imply that cyclists choose a specific lateral position relative to the verge and other cyclists but few studies have tested these assumptions. In the past 10 years, lateral position was studied in a number of Dutch observational studies, mostly reported in grey literature and not specifically focused on the relationship between pavement width and lateral position [15, 16].

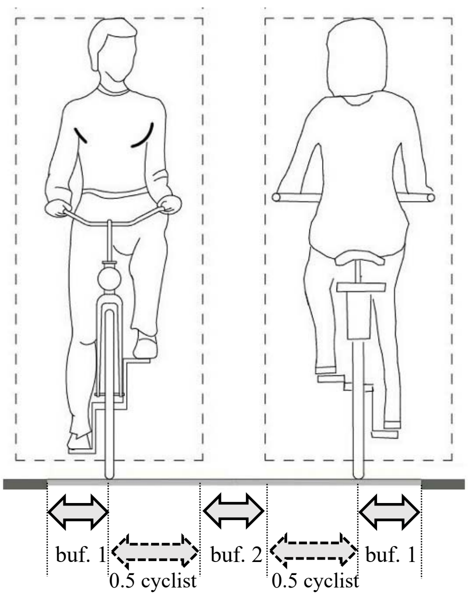


*Figure 1. Lateral space required for cycling.*

The aim of the present study is to investigate the relationship between cycle track width and lateral position. We conducted an experiment in which the cycle track width was manipulated to determine its effect on lateral position. The results have been compared with previous findings from literature.

## 2 DATA AND EQUIPMENT

A group of 24 experienced cyclists between 19 and 27 years participated in the experiment. The group consisted of 11 male and 13 female students from Delft University of Technology (TU Delft). The experiment took place on 8 and 9 December 2020 along a 3 m wide and 120 m long solitary bicycle track at the TU Delft campus. It was chosen because the negligible difference in height between the pavement and the verge would allow cyclists to swerve safely over the verge if needed. To change the width, bicycle tracks were marked using movable white band on the cyclists' left hand side while keeping the real verge at the right hand side. Widths of 1 m, 1.5 m and 2 m were applied. On the 1.5 and 2 m wide track an oncoming cyclist was simulated using a parked bicycle. The middle of the parked bicycle was located 44 cm away from the path's edge as Janssen [16] found this lateral position as average while riding abreast in an observational study. The width of 1 m is less than guidelines prescribe and was therefore considered too risky to include an oncoming cyclist.

After a training trial to get used to the instrumented bicycle, participants rode each of the five conditions (1 m, 1.5 m with and without parked bicycle, and 2 m with and without parked bicycle) three times. The order of the conditions was changed for each participant to avoid bias due to order effects. They cycled on an instrumented bicycle that measured speed by a GPS, lateral position by a LIDAR, and steering angle by a sensor on the steering wheel. A temporary 80 m long and 30 cm high barrier was placed on a fixed 1 m distance from the cycle track to allow the LIDAR to measure the distance between the rear wheel and barrier, i.e. lateral position. One-way repeated analyses of variance (ANOVA) were used to compare steering behavior between conditions.

## 3 RESULTS

The most important variable of this experiment is cyclists' lateral position. Higher values for lateral position are associated with a greater distance from the verge. Figure 2 depicts lateral position in each of the five conditions. Figure 2 also shows the position of the parked bicycle at the 1.5 and 2 m wide cycle tracks. As both the instrumented and parked bicycle were commonly used classic bicycles, the parked bicycle in Figure 2 has the average width of a Dutch bicycle [17].

A one-way repeated measures ANOVA was performed to compare median lateral position at the 1 m, 1.5 m and 2 m wide track without oncoming cyclist. A larger cycle track width significantly increases lateral position ($F(2,130) = 65.3$, $p < 0.001$), an increase of 19 cm if we compare the 2 m wide track with the 1 m wide track. Pairwise comparison with Bonferroni correction shows that lateral position significantly differs between all three conditions.

Two one-way repeated measures ANOVA's were performed to compare median lateral position while cycling on a 1.5 m and 2 m wide track with and without oncoming cyclist. The results show that passing causes cyclists to ride significantly closer to the verge. Median lateral position while passing on a 1.5 m wide track is reduced by 13 cm ($F(1,67) = 111.8$, $p < 0.001$). With a reduction of 9 cm, the decrease is somewhat smaller at a 2 m wide path ($F(1,68) = 46.1$, $p < 0.001$). Minimum lateral distance is relevant for crashes where the cyclist rides off the track. With 15 cm distance from the verge, lateral distance was lowest at a 1.5 m wide path while passing.

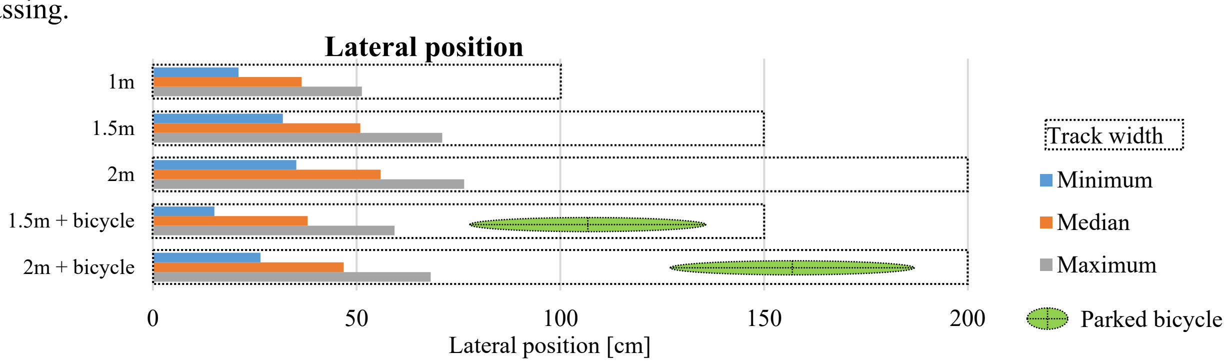


*Figure 2. Lateral position of cyclists at cycle tracks with a width of 1 m, 1.5 m and 2 m.*

Cycle track width significantly increases cycling speed from 14.6 to 15.5 km/h between the 1 m wide and 2 m wide track ($F(2,66) = 4.5$, $p = 0.015$) but the absolute difference is small.

## 4 DISCUSSION AND CONCLUSIONS

This study shows that an increase of cycle track width causes cyclists to ride further away from the verge and keep more distance from oncoming cyclists. The finding that cyclists approach the verge closer at narrower tracks is important as cyclists ride off the track in approximately a quarter of all single-bicycle crashes. Moreover, recent crash studies have shown that reduced pavement width is associated with a higher risk of bicycle crashes. Considering how close cyclists approach the verge and an oncoming cyclist on a 1.5 m wide cycle track, it seems that less width would substantially increase risk, even under favourable conditions. additional results and a more detailed discussion will be added in the full paper.

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